Integral Learning Pedagogical Technique and Distance Learning applied in Laboratory Classes for Electrical and Computing Engineering Schools

Abstract - *This paper presents the results of a PhD thesis research, with an innovative proposal for the development of a Technical Laboratory Disciplines in Electrical and Computing Engineering Schools. The presented system allows that the Teacher-Student interaction and the Teacher support be improved by using IT and Internet Communication. This proposal is an hybrid solution: part online part presential. With this solution is possible to enlarge the delivered contents and learning efficiency of a basic discipline of Electrical and Computing Engineering Curriculum. Another important feature of this methodology is the possibility of ensuring that the approved student in the learning process actually knows the entire transmitted pedagogical content. This proposal is named Integral Learning where is really possible to evaluate the students and to measure the difficulties of them during the respective learning process. This system was tried out for Engineering students and the results are presented in this paper.*

Keywords - *Distance Learning, Internet Learning, Quality Assurance on Distance Learning, Evaluation, Digital Systems Laboratory.*

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1. Introduction

Distance and online learning is nowadays a reality. Since the last decades these referred learning instruments have been using for short duration complementary courses and lately for basic and fundamental courses too. Of course the distance learning permits multiplying the available educational resources. Learning can be done or be complemented in different places other than the school. On the other hand, in the basic education that is developed up to the college, it is not easy to eliminate the predomination of the present teacher, that must conduct the student in his first steps, finding the basic knowledge that will permit him to receive and retain the huge amount of technological information that is generated daily [1], [2], [3], [4], [5], [6].

This work deals with the laboratory basic disciplines in Electrical and computing Engineering courses. Traditionally in the laboratory learning, were possible to find three ways of learning methods:

- Totally presential: this is the traditional laboratory class that have some problems, shown by a field research applied in this work.
- Simulation: the students do not go to the laboratory - software are used for simulate the circuits and processes - of course this solution can not change the real experience got in real laboratories.
- Weblab: sensors are installed in the laboratory, converting the measured variables in signals that are transmitted to a network and received by a remote student - in this case the student actually does not go to the real laboratory too.

This work presents a new pedagogical way for the above mentioned laboratory learning: an hybrid solution - the study and preparation are done online and the laboratory activities are presential.

The other aspect addressed by this work is the evaluation strategy. The traditional learning methods often fail on it. How is it possible to accept that the student that leaves the university does not have the expected knowledge that the own university curriculum establishes ? The presented system, named Integral Learning, using the IT, permits that the students only leave the learning process when they know the entire transmitted knowledge on the respective learning process level. [1], [7], [8], [9], [10].

This article is organized as follows: first, it is discoursed about the distance learning and its application in laboratory engineering courses disciplines. After that, it is commented in which way the Information Technology (IT) can improve the learning efficiency. In the next step, it is presented the target proposal for this study that is divided into field research, system description and its student-teacher-school interaction. After that, a proposal for an innovative procedure for student evaluation and approval, is presented. Finally, the results of a simulation process in an engineering course are shown. The results are discussed and the perspective for carrying out this research, are commented.

2. Information Technology can be used in traditional Universities for improving the Pedagogical efficiency

Of course is possible to amplify the Teacher acting with IT uses and distance learning. As a result of this, the teacher's potential can be saved for more noble activities in the art of teaching. However, one of the critical points in distance learning processes is how to deal with heterogeneously skilled students. The student's assimilation can be done in different ways, many times demanding specific techniques, directed to an heterogeneous public. Traditionally distance learning techniques are not so effective to figure out with student heterogeneity neither with theoretical concepts delivery. Another important point is how to find a way to measure each student difficulties during the online learning process and by this way, to act correctively in this process. This work is now proposing a solution for the above mentioned issues [10], [11], [12].

3. Field Research

Aiming at knowing the reality practiced in Digital Systems Laboratories in the main Engineering Schools, 29 Digital Systems Area Professors of Electrical and Computing Engineering Courses, among 16 important universities, are being consulted. For this universe, it was applied a research about the methods and process used in the Digital Systems Laboratories. The Table 1 describes the consulted universe in the field research [1].

Table 1 - Consulted universe in the field research

Description		Quantity
Universities	Total	16
	Government	7
	Privates / Fundations	9
	Received forms	32
	Teachers	29
	Laboratory teams	140
	Students	670

The following results were consolidated with the research: hosting didactic subjects in Internet is already a reality; the student group structure for the experience execution is held, enabling dependency from some students over others; some professors do not apply a specific test for laboratory courses, mainly due to lack of time to do it; 50% of the professors that replied the research, make a theoretical presentation before the practical experiments in the laboratory, for the student's background; that mentioned presentation is made additionally to the theoretical class of the discipline and takes from 10 minutes up to 1 hour, expending a significant part of the laboratory class and many times it is revealed insufficient; likewise, 50% of the professors that replied the research, consider important to apply a preliminary test before the experiment, with the objective of student's knowledge equalizing and certification of acquirement for the practical activities execution; after asking the professors that replied the research, about who actually applies the preliminary test, it is possible to see that only 20% of that sample effectively do it and the rest of them do not apply it due to lack of time; similarly, only 50% of the professors that replied the research demand written reports for the experiments executed by the students; this way, for the rest of the professors, the follow-up of the real learning of the students is restricted to the tests, which in certain cases can present limited results; it is also mentioned the high frequency of doubt settlement requests by the students to the professor and this fact can conduct to conclude the need for an intensive follow-up process by the professor [1].

4. Proposal for an IT supported Learning processes and Integral Learning for Digital Systems Laboratory in Electrical and Computing Engineering Courses

Although this methodology was applied for Digital Systems Laboratories, such system could be used with small changes, in other knowledge areas. [3], [13], [14], [15].

4.1. Computational Resources

In [1] is shown an Internet Dynamic website as a discipline support resource, that permits the students may interact with the discipline professor and the school. Through that website, the student can develop the following activities: registering in the system; downloading and accessing to the discipline program, downloading and accessing to the discipline support and theoretical background bibliography; downloading and accessing to the content, the project guide, the necessary calculations and basic texts for doing the experiences; doing on-line test of previous certification, on-line test of evaluation and sending these tests to the professor; interacting with the discipline professor, clarifying doubts and receiving guidance; scheduling dates and rooms for the experiments; doing the components and equipment requests for the experiments; requesting additional components and equipments to the laboratory monitor; attaching photos of the most important steps of the experience to the report; doing the experiment and its preformated report; sending the experiment report to the professor; receiving professor comments and the respective grades; presenting doubts and difficulties to the professor, receiving from him, explanations and guidance about the necessary studies for knowledge complementation, in order to reach total skill of the subject of the experiment.

That Internet website permits the professor: to deliver the students general information about the discipline, standards, professor information like name and email; to register the bibliography, discipline contents and experiment guides; to verify scheduled data, time and rooms for the registered students in the discipline experiments; to verify the process course for the registered students in the discipline experiments; to receive the tests and reports from the students; to enable the students to accomplish the experiments; to put the students grades in the system.

The laboratory monitor is a person that is responsible by laboratory activities. He can develop the following activities through the Internet website: receiving the component and equipment requests generated by the students for accomplishing the experiments; verifying scheduled data, time and rooms for the registered students in the discipline experiments; verifying the process course for the registered students in the discipline experiments; taking notice of the enabled students by the professor for the accomplishing of the experiments; receiving scheduled data, time and rooms effected by the students, for all them presential activities developed in the university laboratory. Further, the students can use the computer for: consulting electronic components data-sheets available in manufacturers websites; using circuit simulation software and others activities [16], [17].

4.2. Laboratory Physical installations

The laboratory is composed by the standard measuring instruments and Digital Systems experiments tools and the computational resources like one microcomputer for each work bench, so that the students can do the experiments with interactivity with the discipline website. The work benches microcomputers are connected in network and also connected to a server microcomputer that is operated by the laboratory monitor. This server must have a printer under the laboratory monitor responsibility. Through this server, it must be possible tracking and registering all the student visited Internet websites in each work bench computer, avoiding, this way, the access to unauthorized and out of class subject websites. The microcomputers in the laboratory work benches must be connected to digital photographic cameras in order to register all the important steps of the experiment. Those photos must be attached to the experiment report. All microcomputers must be protected by updated antivirus software [1].

4.3. Basement for the experience

The professor starts the process of the present experiment, enabling the Internet access for it. At the same time, the time count for the experiment execution is initiated. The student accesses the discipline Internet website, acquaint oneself with the discipline contents, selecting the present experiment and registering himself in the system for this experiment. He must read the basic recommended bibliography for the theoretical basis necessary for the execution of the experiment. Further, the student must do all the projects and calculations necessary for this preparation. When the student is sure that he is able to execute the experiment, he must do the online qualifying test for certification of capability of doing it. This test is time-controlled, time-measured, personal, and under supervision. In order to do the qualifying test, the students must keep in touch with the laboratory monitor who, by using his password, will enable the beginning of the test in a microcomputer located in a specific room. In this room, there is a video camera for image recording. Thus, it is possible to confirm the identity of the student that is doing the test. The professor will receive the accomplished test, correcting it and publishing the grade. The grades will be informed to the students, through the Internet website and the students must confirm the knowing of the grades. Only the student that gets the maximum performance in the accomplished test will be able to do the experiment. Should the student not present this result, the professor will propose, by email, new readings to the student and he is going to do a new test, aiming at the certification. This process will be repeated until the student is qualified. When it occurs, the student will receive the permission for doing the experiment, being enabled to schedule this step. This way, the student must schedule date, time, make the room reservation and the equipment and component requisition. Every student that exceeds the defined time for the certification stage or miss the respective test, will receive a grade penalty, according to the rules defined in the chapter: Evaluation and approval procedure [1].

4.4. Execution of the experience

After scheduling the experiment, the students can be distributed in different groups in each experiment. This fact can avoid the dependency that some students have over others. In the scheduled date and time, the students will be present at the reserved room for the execution of the experiment, identifying themselves to the laboratory monitor. With the requested equipment and components, the students will start the experiments, using the guide available in the discipline Internet website. This guide is interactive, containing questions about the respective experiment stage, also measuring the time spent on each one. Following the specific instructions of the guide, the students will take photos of the requested steps of the experiment, attaching the respective photos to the experiment data report. After finishing the measuring and answering the presented questions, the students shall make available the experiment report to the professor, by the Internet website. The professor will evaluate the students report considering aspects like data consistence, answers to the questions presented during the experiment and also computing the expended time to the execution of the experiment. After that, the students must do the final certification test, with questions that will involve aspects related to the executed experiment. This test is also done under supervision and time-controlled, time-measured and must be done also at the university, in the same date of the experience or not. The procedures will be the same as those used in the initial qualifying test. The test, after concluded, will be available to the professor that will emit the respective evaluation. The results will be informed to the students by the discipline Internet website. As the next step, the students must fill a preformated report, detailing their doubts and difficulties in all of the concluded process. The professor will analyze the emitted report and considering the student's accomplishment during the experiment and in the final test, he can, at his discretion, present to the students, guidance about the necessary studies for complementing their knowledge in the unclear points, and also propose the re-execution of the experiment in another date and time. The student that missed an experiment will receive a grade penalty according to the rules defined in the item: Evaluation and approval procedure. Should the professor consider the reasons given by the student not justified, he will not be approved in the present experiment [1].

4.5. Evaluation and approval procedure

The traditional evaluation and approval criteria in learning, regardless of the type of course, level or academic stage, assign grades to the activities executed by the students, among a scale from 0 to 10, corresponding to 0 to 100%. The threshold grades change in each school and might be, most of the times, 50 or 70%. It means that if the student is approved with the grade 70%, it is accepted that he does not know at least 30% of the delivered content charged in tests and works. More serious than this would be the case of the 50% approval criterion, where it is accepted that the student knows only a half of the taught subject in the respective course. How is it possible to accept that the professional that leaves the university does not have the expected knowledge that the own university curricula establish as important to the formation of that same professional ? It is to wonder if the blanks detected by the evaluation process along the several available courses will not be felt in the accomplishment of those professionals egressed from the schools that use threshold grades of 50% or even 70%.On the other hand, with the traditional learning and evaluation methods, it becomes extremely hard to change the parameters described above. The question is how to permit the approval of only the students that know 100% or approximately 100% of the taught topics during the course ? Once the students are not totally homogeneous in their basic knowledge level and they present variable learning curves, a learning system that proposes taking the totality of a class to an almost excellence level, must obligatorily treat each student in a different way, using interactive processes and frequent evaluations. [18].

The evaluation method, grades and approval criterion, presented in this system integrated with IT, which is proposed for the Digital System Laboratories, only permits the student to reach the next step or be approved in the discipline, if he indeed knows the course delivered contents deeply.

Two types of grades are defined: the grade that the student obtains in each stage and his accumulated grade. The student always goes into the process of each experiment with an initial accumulated grade equal to 10. As the student passes through the several stages of the experiment process, he can lose points if he does not reach some defined objectives for each evaluation test and for the experimental part of the experiment. Missing the test and experiment and not reaching targets and deadlines will also make the student lose points.

In the qualifying stage, the student must get the necessary knowledge for doing the experimental part of the experiment. This will be evaluated by the qualifying test, that can hold or reduce the initial accumulated grade equal to 10. Should the student not obtain the maximum performance (qualifying test grade equal to 10), he will have his accumulated grade reduced to a value less than 10, according to a previously defined rule.

This way, the student will not be allowed to the experimental part. He must contact the professor and under his supervision, redo partially or integrally the research and the initial reading, preparing himself for a new evaluation test. Every time the student comes to the initial stage, once his qualifying test grade is less than 10, his accumulated grade will be reduced. The professor will follow the student's accomplishment and when his accumulated grade reaches a value less than or equal to 5, it shows that the student is not evolving in the learning process. Thenceforth, the professor must intercede, contacting the student personally to know which his difficulties are. The professor can at his discretion, reinsert or not, the student in the experiment process. Should the student not reinsert in the process, he will receive grade zero in this experiment. Being enabled, the student will schedule and execute the experiment. The experimental stage will generate a grade, based on the consistence and correction of the report sent to the professor and also based on the time the student spent to do the experiment. This grade, being less than 10, will cause the reduction of the accumulated grade that the student obtained after the qualifying stage, according to a previously defined rule. After doing the experimental part, the students will do the final certification test that evaluate the obtained knowledge with the experimental part as well as their technical knowledge related to this experiment. The final test will generate the third grade of this process, based on the answer to the questions and on the time spent by the students to do the test. Similarly to the previous stage, this grade, if less than 10, will cause to reduce the accumulated grade that the student obtained in the experimental part, according to a previously defined rule. It will be considered approved, in the respective experiment, the student that obtains maximum accomplishment (grade equal to 10) in the experimental part and in the final test. The student that was not approved must present the professor a filled perform report, describing the doubts that he still has and after online and personal contacts with the professor, redo the process: experimental part and final test until he obtains in the last stage, the maximum accomplishment (grade equal to 10). Every time the student comes to the last stage, once his qualifying test grade is less than 10, his accumulated grade will be reduced, according to a previously defined rule. Similarly, the professor will follow the student's accomplishment and when his accumulated grade reaches a value less than or equal to 3, it shows that the student is not evolving in the learning process. Thenceforth, the professor must intercede, contacting the student personally to know which his difficulties are. Similarly, the professor can at his discretion, reinsert or not, the student in the experiment process. Should the student not be reinserted in the process, he will receive grade zero in this experiment. The final accumulated grade represents, in an inverted way, the difficulty level that the student showed to get the maximum accomplishment in the respective experiment and it is possible, with this parameter, to evaluate the entire learning process.

5. Tests and simulation

The proposed system was applied to 10 third series Electronic Engineering students of the Universidade Presbiteriana Mackenzie in São Paulo, Brazil [1]. The students have done one complete experience according the criteria described in chapter 4 of this paper.

The Table 2 presents the time expended and the Accumulated Grade got by the students in doing any step of the experience process.

Table 2 - Time expended and Accumulated Grade in Process Simulation

Students #	Habilitation Test		Experience - A1			Experience - A2			Experience - A3			Final Test	AG	Total Time
	A1 (min.)	A2 (min.)	M (min.)	D (min.)	R (min.)	M (min.)	D (min.)	R (min.)	M (min.)	D (min.)	R (min.)	(min.)		(min.)
1	85	65	60	60	50	--	--	--	--	--	--	125	**7**	445
2	45	--	45	25	40	--	--	--	--	--	--	60	**10**	215
3	45	--	45	25	40	--	--	--	--	--	--	60	**10**	215
4	75	--	45	25	40	--	--	--	--	--	--	60	**10**	245
5	55	65	75	--	--	80	--	--	--	60	30	95	**7**	460
6	55	--	75	--	--	80	60	30	--	--	--	95	**8**	395
7	70	60	80	--	--	--	50	40	--	--	--	85	**8**	385
8	65	75	80	--	--	--	50	40	--	--	--	85	**8**	395
9	40	--	50	15	35	--	--	--	--	--	--	45	**10**	185
10	35	--	50	15	35	--	--	--	--	--	--	45	**10**	180
Average Time	**57**	**66**	**61**	**28**	**40**	**80**	**53**	**37**	--	**60**	**30**	**76**	**9**	**312**

A1 - First time student did the step A2 - Second time student did the step
A3 -Third time student did the step M - Mounting of the experiment
D - Circuit Debugging R - Report generation AG - Accumulated Grade
Remarks: (1) Every time the student has to go back and doing again some part of the process, he loses 1 point of the AG. (2) Time is measured in minutes.

The students found favorable aspects in the applied system such as:

- Preformated reports. Online eletronic reports with all levels photos.
- Preparation for the experiences. Done in advance (in any place and in any time). It is possible to anticipate activities.
- Strategy for knowledge equalization before the practical experience. Deal with heterogeneously skilled students
- The habilitation test acts as a process input filter. It demanded that the students studied more.
- In the second time that the students did the test, the results were always good.
- Many activities occurred on evenings and on weekends (in any place and in any time).
- The email communications did well in all levels and documented all the process of the simulation.

6. Summary and future work

This article describes a system for enlarging the efficiency of learning in Digital System Laboratory in Electrical and Computing Engineering Schools, using Information Technology (IT) and the Internet access.

Distance and Virtual learning are not new concepts. However this work proposes the application of the most efficient aspects of the Distance and Virtual Learning to a Basic Discipline Laboratory.

Some questions addressed by the proposed system are: improving the professor's interaction; multiplying the professor's presence and his support for the students using IT and the internet; joining the flexibility of distance learning with the interactivity and the intensive support of the traditional presential learning; permitting to enlarge the delivered contents and learning efficiency of a basic and conceptual discipline; permitting to ensure that the approved student actually knows the entire transmitted knowledge and measuring the difficulties of each student in passing through this learning process [19].

This way, the proposed system, compared with the traditional existing methods can develop solutions for: time flexibility for all students activities; possibility of preparation of the students for the experiments in any place and in any time; possibility of student knowledge equalizing before the experiments; besides the theory introduction and all the necessary information, the students can download the experiment guidance by the internet, in order to prepare the practical activities and settle doubts before the experiments; expanding the theoretical presentation time, up to the really necessary time for giving background to the students and settling their doubts; permitting flexibility for the student group structure in each experiment, avoiding dependency from some students over others; time flexibility – the student can set up the execution of the tests and the experiments according to their availability, under the university schedule; continuous evaluation; online and continuous student activities verification by the teacher; teacher support in any place and in any time; learning process evaluation; student certification – he does not leave the process, while he has doubts about the subject in course; possibility of measuring the difficulties that each student has in passing through the learning process, using an evaluation parameter; learning process evaluation with the same parameter; total learning process documentation [1], [19].

Once the proposed learning system is based in IT, it is possible to use the same resources to implement some additional facilities. In order to reduce some student difficulties, some short duration video courses can be created and make available for the students. These courses can show mounting techniques, instrument operation techniques and other student needs.

This system could be implemented by using a new specific web-based system or adapting some of online education computational environments, like BlackBoard, Moodle, WebCT, COL, AulaNet, Platine and others [1].

Of course that for the implantation of the described methodology it will be necessary changes in the pedagogical contents generation by the teachers and more technological investments by the universities [20].

All the system levels were modeling in UML (Unified Modeling Language) in order to make easy it implementation. The next steps of this work will be: the development of the necessary web-based system and apply it in a real discipline of a real course, adapting some parameters and rules.

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