A technological platform for the teaching of control engineering

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***Abstract*— This paper presents a technology platform as a resource for the teaching of control engineering. The platform in question combines the educational potential of software of design and simulation of control systems - MATLAB ® - and the connection between this software and a pilot distillation column. The research hypothesis is that the use of technology platforms such as this helps to develop aspects not only stimulated with simulation. Therefore, an experiment based on the constructivist and social-interactionist theory has been designed to detect student development and to capture their impressions of the platform. The results are presented as graphs and impression reports of the teacher.**

Keywords-technological platform, control systems, constructivist theory.

I. INTRODUCTION

Emphasis on the teaching of techniques instead of concepts results in a fast forgetfulness by students. The teaching of theory detached from practical aspects does not properly prepare the student for his professional life [12].

Nowadays, the teaching of engineering and the methods used by teachers do not significantly contribute to the development of skills and competences needed by professionals, especially in a control engineering and automation course.

The theories selected for didactical and pedagogical conception of this platform have as their main argument the attempt to approach teaching of engineering – typically instructionist – to the most adequate paradigm for building knowledge and inherent competences to this professional, opposed to the positivistic and behaviorist theories that prevail in this segment of higher education. Such platform, which has a system and control project and simulation software and integration between the simulation software and a real scaled system, provides students with a favorable environment to the development of competences and skills required to their jobs.

According to [11] recommendations by the Accreditation Board for Engineering and Technology (ABET), an American institution that aims at establishing specific quality criteria for each major, undergraduate courses should encourage the ability to apply knowledge of mathematics, science and engineering; design and conduct experiments; analyze and interpret data; design a system, component or process to meet desired needs; function on multi-disciplinary teams; identify, formulate and solve engineering problems; understanding of professional and ethical responsibility; communicate effectively (written and orally); understand the impact of engineering solutions in a global and societal context; engage in life-long learning; use the techniques, skills and modern engineering tools necessary for engineering practice.

Through an appropriate computational support, this professional in formation has access to common problem situations in their professional environment, as long as a didactical and pedagogical strategy by the teacher favoring the student's production/authorship and development is used in association. To do so, certain aspects must be outlined, such as the evaluation process.

In engineering courses, teachers, who are excellent conveyors of knowledge – as if knowledge could be conveyed and not built – usually regard evaluation as a confrontation process between the teacher's questions and the student's answers, searching for an approximation measure between both to generate a likely grade or concept that represents the entire individual learning throughout the term.

Following the knowledge building process implies favoring student's development, guiding them in tasks, offering new references or explanations, suggesting investigations, providing enlightening experiences to foster knowledge expansion [6].

Within the context of a formation based on paradigms that originate from constructivism, critical-dialogical and social-interactionist pedagogies, educational evaluation is not something detached from the large procedural set that configures formal school and college education. It is intrinsic to educational practice, teaching and learning [1].

However, a learning evaluation process should be continuous and present throughout the entire teaching-learning process, a limited evaluation such as a test is not able to represent all the knowledge built in the student's cognitive structures.

This study is structured as follows: the second section presents a brief state of the art of using similar technological platforms; the proposed technological platform is presented in the third section, stressing its main constituent components. The fourth section presents the proposal of a didactical-pedagogical experiment, and the fifth section brings the results of the case study. Final considerations are discussed in the sixth section.

II. A BRIEF STATE OF THE ART

The state of the art that congregates several studies related to the proposed platform can be quite briefly approached in the following paragraphs. It is important to stress that, in spite of the similarity of the proposed platform with varied remote laboratories mentioned in the studies below, this work aims at using the technological resource as a facilitator for a didactical-pedagogical experiment to investigate the importance of this platform for the teaching of control engineering and automation.

Aktan et al. [2] use the paradigm of distance learning, in which students, teachers and equipment are geographically separated, to develop a remote access real-time laboratory to teach control engineering. The entire apparatus enables students to develop and depurate distance programs and then carry out online experiments to control a robotic manipulator.

Liou et al. [7] used the Labview software to control electrical systems, such as RLC circuits and electric engines. Users use the Internet to access Labview parameters and are able to interact with the systems simulated by it.

Schmid and Ali [10] developed an Internet-based system to teach control engineering. This system enables a more comprehensive visualization and simulation of dynamic systems due to use of a standard web browser. Virtual Reality Modelling Language (VRML) is used to animate dynamic systems. In addition to these resources, the virtual course is composed of tutorials, exercises and virtual experiments.

Clume and Gomes [4] presented a system for remote control of real-time processes using the Internet, following a client-server architecture. A project interface and fuzzy controller tuning is made available for the user. The remotely accessed equipment is a pendulum. Tests were performed at Universidade Federal de Juiz de Fora (UFJF) and at Universidade Federal de Santa Catarina (UFSC) to validate the capacity of system remote access.

Zeilmann [13] presented a proposal of control, supervision and monitoring of industrial processes by the Internet. He presented the study under the perspective of three contexts: industrial plant, server and client. Through integration of web technologies and fieldbus networks, it provides remote access for users to the devices communicating via Foundation Fieldbus protocol. It is an advancement in relation to other remote laboratories due to the proximity between the pilot plant and those found in the industry.

Casini et al. [3] developed a laboratory for the remote teaching of process control techniques. Control modules available at the laboratory are position control, speed control, both of a DC engine, tank level, and helicopter simulator.

It focuses on competition between users and their control algorithms, creating a ranking for those who develop algorithms with better performance.

Dormido et al. [5] presented an online laboratory for experiments in a non-linear, multivariable system, three attached tanks, enabling students to learn in practice essential aspects of process control. Through the integration of EJS (Easy Java Simulations) and eMersion – collaborative tool for online experiments – people involved can have greater flexibility to perform experiments.

Based on this scenario, it is possible to observe a main focus on verification of tool quality only quantitatively and in the process of building such technological platforms. This study aims at observing the student's evolution during use of the tool, which basically takes an entire term, using two verification tools: a questionnaire for students and the records of a teacher's impressions.

III. THE PROPOSED TECHNOLOGICAL PLATFORM

Development of a technological platform for the teaching of control engineering and automation must pass through use of existing and available computational and technological resources at the laboratory of industrial automation of Instituto Federal Fluminense. These resources, commonly explored separately, now start to integrate an environment of project, simulation, implementation and tests for advanced control strategies.

Differently from many laboratories with remote access available in teaching institutions around the world, this laboratory aims to serve as foundation for studies by students enrolled in a regular and in-person course, making clear that the intention, at least not initial, of this study is not to investigate the advantages of these laboratories for distance learning.

The platform has three basic constituent elements:

- Real system, represented in the form of a pilot distillation column.
- MATLAB/SIMULINK®, control system project and simulation software.
- Integration of the above software with the real system through a mediation and acquisition system of industrial data – Foundation Fieldbus (SYSCON®) and the OPC servers that integrate Smar® SYSTEM302 package.

The choice for proprietary software is due to the fact that there is no equivalent software for function inherent to application, stressing that all software used is properly licensed. Figure 1 presents the constituent elements of the platform in the form of a diagram.

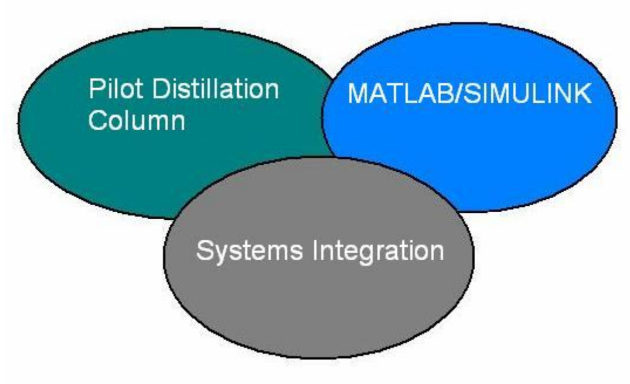

Figure 1. Components of the technological platform.

A. The Distillation Column

In many laboratories of the automation course of Instituto Federal Fluminense, there are prototypes of industrial plants and processes. Through systems of data measurement and acquisition similar to those used in industrial environments, these prototypes allow students to interact with the equipment and learn techniques of process control identification, which are used by control and automation engineers. Among existing laboratories, the pilot distillation column is closest to an industrial process in terms of instrumentation system and productive capacity. A picture of the distillation column can be seen in Figure 2.

Figure 2. Pilot distillation column.

B. Integration of Communication Software

This column has a supervision and control system quite close to the reality found in transformation industries, which base their processes in distillation, such as sugar mills and oil refineries.

Integration between SYSCON® and its installed OPC servers enables access to parameters of the instruments connected to the plant, which allows measurement of variables and acting in final control elements, such as flow control valves. Such availability of data will be used by MATLAB® for the last integration level, enabling control of the distillation column.

C. Project and Simulation Software

MATLAB® has great acceptance by engineers because it has toolboxes for many areas of scientific knowledge, especially engineering courses. In terms of control engineering, it has a graphic environment that works with the concept of block diagram and signal flow for the project and simulation of control systems known as SIMULINK®. After version 7, MATLAB® gained a specific toolbox for OPC communication, which is the most widely used dynamic transference protocol in the industry. This allowed the integration between a software program used at the university and industrial equipment, such as distillation column instruments.

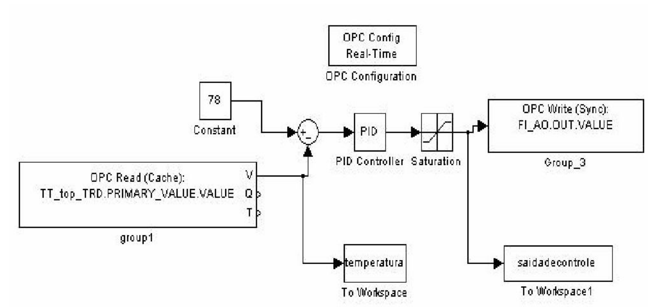

Figure 3. Control system with OPC communication.

Figure 3 shows a SIMULINK® screen with an implemented control system accessing instrument parameters from OPC communication blocks. Projected and simulated control systems by students can then be tested in the real system.

IV. EXPERIMENT CHARACTERIZATION

The didactical-pedagogical experiment was performed at Instituto Federal Fluminense and used as empirical field 8^{th}-period students of the Control Engineering and Automation Superior Course, more specifically students enrolled in the advanced control course.

Certain aspects should be observed throughout the term so that, by the end of the course, it is possible to collect data and analyze results under the light of involved theories.

Taking such aspects into consideration, constituent steps are presented in the characterization of the didactical-pedagogical experiment.

Among these steps, the following stand out:

- Laboratory physical structure. Students use desktop computers with 2.4 GHz Core 2 Duo, 2MB cache, 2GB RAM, 120GB hard disk SATA, 19" Widescreen TFT LCD monitor in conformance with ABNT norms, ABNT2 keyboard. These PCs are connected to a Hub along with the Device Fieldbus Interface

(DFI), allowing access to the plant by all computers. License for MATLAB® version R2006a for up to 20 network machines.

- Verification of impressions relative to students' progress in the form of daily records made by the teacher. Excerpts of these records are shown in section 5.
- Record of students' impressions in relation to the platform. A modified version of the SERVQUAL tool – applied in verification of service quality – was used; further information will be presented in section 5.

This experiment proposes that during classes the teacher should provide idealization and problems for the student and play the role of a possible partner in the teaching-learning process either as a student helper or as an encourager of new investigations.

The steps of the suggested methodology to define and execute the experiment are based on the premise that it is not correct to see teaching-learning processes as a paralyzed process starting at a given point and ending at another with an evaluation of concepts. It should be regarded as a continuous process fostering daily progress and requiring periods of reflection between sequence processes of assimilation and accommodation and resulting in the much outlined reflexive abstraction [9] originating not only from the individual's actions, but also from action coordination.

Within such reality the proposed technological platform is inserted as an environment in which students are able to design, simulate and implement advanced control systems and test their performance on the pilot distillation column.

V. RESULTS

Results were divided into two parts; one concerns the reports of teacher's impressions in the classroom, and the other is relative to verification of an existing gap between students' expectation and perception when using the proposed computational platform.

Parasuraman et al. [8] presented the methodology used to create the SERVQUAL scale. It is an interactive process of quality assessment of five companies in the segment of services in the 1980's in the USA and subsequent verification of internal consistency of the questionnaires using Cronbach's alpha coefficient1. The authors reduced 150 original items to a questionnaire with only 22 items, which can also be reduced. This study only used ten items to be included in the questionnaire applied to students.

Choice for the SERVQUAL scale in this study was motivated by the facility to quantify subjective values and impressions of clients (students), and its important capacity to demonstrate the gap between expectation and perception by making verified aspects a little more tanglible.

Students evaluated each of the ten items in relation to expectation and perception. To do so, they had to sort the items into one position in the numeric scale composed of seven positions known as Likert scale2 because of its level of agreement with the presented statement. According to the excerpt taken from the questionnaire:

The technological platform helped performing the tasks.

1	2	3	4	5	6	7

Other examples of statements include the following: The technological platform is essential to perform the tasks; The platform was relevant to consolidate the concepts learned in the classroom; The technological platform helps us develop competences required to our professional formation. Ten statements were used. Based on the collected data by the questionnaire, it was possible to graphically establish the difference between expectation and perception in terms of response frequency, resulting in the chart shown in Figure 4.

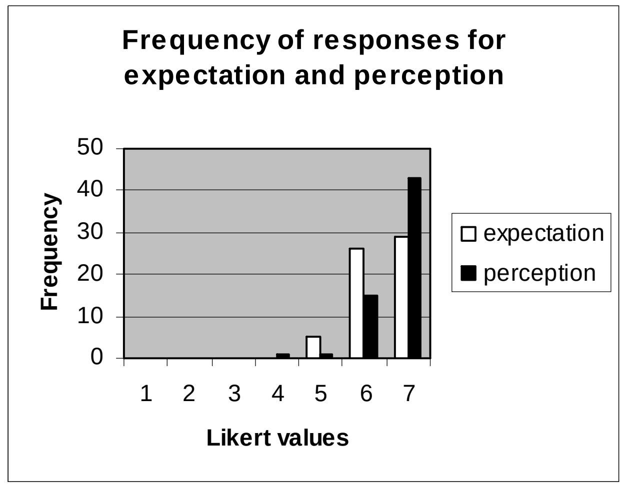

Figure 4. Response frequency chart for expectation and perception.

The chart in Figure 4 shows a quite high frequency for number 7 in terms of perception. It can be concluded that for most questionnaire items the students strongly agree with the proposed statement. The high frequency for numbers 6 and 7 in terms of expectation suggests that students had a good expectation toward the tool, which is positively confirmed in perception.

Students' follow-up throughout the term was performed on a daily basis by the teacher of advanced control. Only a summary of his impressions will be included in this paper, focusing on the most relevant impressions. The group is composed of eight students in the eighth period of Control Engineering and Automation. All the excerpts below refer to the teacher's statements.

> *In general, students had an excellent performance in this course. Such performance was seen by the*

[1] Cronbach's alpha is a coefficient used to measure the internal consistency of questionnaires.

[2] Likert scale is a five- to seven-point scale used to quantify subjective aspects.

end of the term, but knowledge was built at each interaction in class.

Based on the teacher's comments, it is possible to note that students' progress during the term was evident, reflecting in performance results by the end of the term.

First students had expository classes of theoretical background about the main techniques of advanced control.

At a given point, students were explained about use of the technological platform proposed for development and application of advanced control systems.

Theoretical background was necessary to make students more able to achieve the objectives proposed in subsequent stages.

From then on, students were encouraged to work on projects and solve specific control problems using the platform. In many classes students had initiative and helped each other, showing ability for team work.

By working with a new class model that favored participation and production, and encouraged to work on projects, there was an adequate environment for the development of highly valued competences, such as team work.

An assignment by the end of the term in which students had to design, implement and test an advanced control system using the proposed platform, showed they were already able to manipulate the tool. By the end of the term, students presented their projects and control systems, which were working according to specifications.

It is possible to observe that they developed the main competence required to a control and automation engineer, that is, development and application of a control strategy for industrial processes.

VI. Final Considerations

The proposed environment aims at providing students with a favorable environment for the development of competences and skills required to a control and automation engineer, such as those presented in [11]. It was able to achieve the objective based on analysis of results.

The didactical-pedagogical conception of the experiment and analysis of results were developed to approximate constructivist theories, especially in aspects regarding proposal framework and tools used to obtain the results. Results achieved by application of tools were considered satisfactory for a pilot study. Such statement can be confirmed by presentation of results as a chart, showing acceptance of the platform by students, and also by the teacher's reports.

Further studies include application in other advanced control groups and development/use of new tools to follow the students' progress throughout the term, such as a daily report.

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