Proceedings of the 17th World Congress
The International Federation of Automatic Control
Seoul, Korea, July 6-11, 2008

# Blended Learning using GCAR-EAD Environment: Experiences and Application Results

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**Abstract:** This paper presents results and experiences of the application of an educational tool called GCAR-EAD Virtual Learning Environment in control systems lessons at the electrical engineering department of our University. The environment offers besides traditional organized educational material also remote experiments and a preliminary tutoring system that guide the student in order to maximize knowledge transfer and self-learning techniques. MOODLE as common virtual learning platform was employed as basis of the environment architecture and several developed tools were integrated to increase the added educational value of the system. Results and students feedback indicate good educational value associated with the system and further development is addressed to enhance the blended learning scenario and effectiveness of the system.

## 1. INTRODUCTION

The increasing employment of collaborated and blended learning techniques by educational and training institutes indicate that this kind of solution maximizes investments whether the growth of students demands more resources and teachers. Although any computer-mediated communication (CMC) suffers when compared with its face-to-face equivalent, the blended learning scenario takes advantage of face-to-face and remote (distance) education. Most of virtual learning environments (VLE) used for distance learning offer collaboration (team and distributed learning; Auer, 2003) and self-learning (active learning) concepts. A tight couple between the traditional and the "virtual" lessons can be achieved by the proper application and development of didactic materials and tools that supply the coupling.

Remote practice enhances blended learning lessons supplying real applications to theory lessons. According to Atkan (1996), the SBBT (Second Best of Being There) solution for remote practice has become an attractive economical solution to experiences used in educational institutes. Following this trend, many institutions around the world have been engaged in the development of Web-based experimental settings (Cooper, 2000). Systems aiming at teaching and research in several different areas have been proposed, such as digital process control (Ramakrishnan, 2002), PID control (Batur, 2000), embedded communication systems (Schmid and Ali, 2000), supervisory control (Lee and Hsu, 2003), robot and other systems teleoperation (Huijun and Aiguo, 2007), and real-time video and voice applications. Mostly, these experiments employ customized devices and software to make small-scale textbook-like experiments remotely available.

However, our experience has shown that the availability of remote experiments is not a sufficient condition to ensure success in the learning process construction of engineers. Remote lab experiments that are offered as "stand-alone" settings, without connection to adequate learning material (explaining the topics that are to be learned in the experiment), usually lead students to the use of a "trial and error" strategy, which has a lower learning impact than originally expected. Moreover, remote labs that are made available 24/7 for a large audience of students increase the demand in the number of faculty members and tutors that are necessary to provide on-line guidance to students.

An environment which integrates collaboration, didactic, and remote practice is ideal for the training and education of future engineers. State of art technologies applied to remote practice offers a link between real and simulated experiments creating a mixed reality experiment taking advantage of both "worlds". The proposed environment includes functionalities to arrange the cited advantages and technologies in an easy to use Web interface available for all students.

This paper is organized as follows: section 2 presents blended learning scenarios (advantages) and related works; section 3 describes the GCAR-EAD environment; in section 4, some results of the educational application of the environment are presented; finally, section 5 draws conclusions and future work on the running development is presented.

## 2. BLENDED LEARNING SCENARIOS

Blended learning is the technique were traditional lessons are mixed with virtual remotely/e-learning (or distance) lessons. This kind of scenarios opens up several advantages that in traditional lessons are not commonly available. The employment of Web as medium in part of the lessons broadens the knowledge and makes use of state of art technological advancements possible. Internet accessibility offers integration with any available knowledge database not only constraint to our institute.

The application of blended learning scenarios in education is not new, but still very pertinent to the development and research of other techniques and tools that enhance knowledge transfer and collaborative learning strategies. Previously, in traditional face-to-face courses, it was assumed that teachers were the source of knowledge and they centralized all courses information. Using a collaborative learning approach, student teams (or users in general) may work together increasing the knowledge transfer in a common environment. This is the very essence of the social constructionist pedagogic line, focus of the MOODLE implementation.

These scenarios support distinct learning concepts: active learning, distributed learning and team learning. Active learning skills are justified since, via environment interactions, students can "self-learn" (or self-teach). Distributed learning skill is obviously linked to the spatial flexibility characteristic offered by VLEs Web-accessibility. The most important skill is however related to collaborative interaction, *i.e.*, student teams (or users in general) may interact, even more than in traditional classrooms, sharing the knowledge in intra group as well as inter group activities. The activities often involve tutors that also share and collect knowledge collaborating with students.

A good example of blended learning lessons is a: well-structured introductory lesson in the classroom and after that provide follow-up materials online, often organized in VLE/LMS (Learning Management System) or similar. The guidance in this method is suggested early in the process, to be faded as learners gain expertise (Kirschner, Clark and Sweller, 2006).

Our applied method uses traditional classes allied with online activities like: home-assignments, tests, tutorials, theory learning materials, and most important, remote practice. The online environment is structured to offer easy to use intuitive interface. Students enrolled in the traditional class are also enrolled in the online course of the virtual environment, which displays information/data parallelly to the given face-to-face class.

The virtual environment also offers experiments (using the SBBT concept) to confront the theory. The experiments are related to theory concepts that need special attention. Real experiments are not always available nor present in the real laboratories of our university. To overcome this problem, computer simulations mimic real equipments behaviour, or only one remote experiment installation is developed to all students. This kind of solution is becoming very popular among institutions with low budget. The practice plays a key role in education, hence, affordable solutions for high quality education versus cost are in the spotlight of the scientific community.

Although there are several interesting related works published in the literature, there is no identification of any solution integrating all concepts incorporated into GCAR-EAD and applied to blended learning in education.

Szczepanski and Hadlich have reported interesting implementations of Foundation Fieldbus interface using OPC (Szczepanski and Hadlich, 2003) in which the remote operation is possible and the OPC communication is "transparent". FF Pilot Plant similar experiments were encountered: OnlineLab (Duan, 2003), Automatic Control Telelab ACT (Casini, 2004) and others.

Several projects have employed and tested remote experiments networks like: LabNet (Davoli, 2001), PEARL (Ferreira *et al.*, 2002), CyberLab (Haugom, 2006), VVL (Fearns and Baumer, 2002). MARVEL (Michaelides, 2004) and others.

The system proposed by Bruns (Bruns and Erbe, 2004) is an excellent example experiment with mixed reality techniques integrated in the VLE with collaborative and distributed learning methods. But this solution has no learning materials associated with the experiment, no specific experiment goals nor experiment feedback. Thus, the user (student) is not guided nor receives any analyzed results of the performed experiment, even though this system supports such enhancements.

The Solar Energy e-Learning Lab (Michaelides, 2004) has an integrated learning system with several learning materials and "quizzes" to identify student understanding level. First, the student must pass several experiment theory tests, so that the system grants remote experimentation access. Despite these qualities the system also does not offer experiment feedback.

Other known experiments (Casini, 2004; Albu *et al.*, 2004) do not have at least VLE integration, though all have excellent remote experiments with lots of different and distinct equipments.

The Automatic Control Telelab (ACT) proposed by Casini (Casini, 2004) offers not only controller parameterizations, but also MatLab Simulink models to describe and characterize the controller logic. This interesting approach is very useful in the experiment configuration. By applying this technology the experiment is much more flexible since students can design their own controller (surely that it must pass through security checks).

## 3. The GCAR-EAD

The GCAR-EAD environment was a natural successor of previous works that led only in interfaces to remote laboratories. Experiences using the Foundation Fieldbus pilot plant, in previous work (Zeilman *et al.*, 2003), showed that due to the fact that the learning material was "loosely coupled" with the remote experiment, students were not able to identify which topics to review in case they could not get the proposed experiments adequately done.

In order to overcome those drawbacks, a system called GCAR-EAD was proposed, which supports remote experimentation and mixed reality. The GCAR-EAD has a more complex architecture, that additionally integrates a learning material manager (LMS/VLE), educational materials, remote mixed reality experiments and mixed reality concepts, interchangeable components strategy (Schaf and Pereira, 2006), experiment analysis and simple student guidance tools. The proposed architecture has five main modules: learning (didactic) material manager; student guidance system (or student guide); experiment booking; experiment analysis (or experiment analyzer); and experiment manager/interface. Each of these modules is responsible for controlling a specific functionality of the GCAR-EAD environment. The interaction with each module is transparent, so that students only "see" the VLE.

*Learning Material Manager*

This module contains all didactic materials of the GCAR-EAD and monitors all students' interactions. All users are identified via username and password and depending on users' category and, in case of students, knowledge level, distinct operations are allowed when accessing available learning material.

*Experiment Booking Module*

This module is responsible for controlling the access to experiments by students. Since real experiments are not replicable, booking systems are necessary to organize the use of the real equipments (or entire real experiments) by the students. User/password information stored in the VLE is checked so that only signed VLE users can book/access experiments. Validated users can select one of the available time slots (1 hour each) for running their experiments.

*Experiment Interface/Manager Module*

The experiment manager provides a link among the remote experiments and the VLE and must ensure that the right remote experiment interface is available according to VLE set-up parameters. That means, the experiment manager receives from the VLE a reference to the experiment to be executed and "constructs" the experiment providing also a Java Applet interface for data visualization.

This module is also responsible to implement the interchangeable components strategy by linking and combining real and virtual components in a learning scenario.

*Experiment Analysis*

The experiment analysis module comprises tools to evaluate the results of a conducted experiment and determine – based on some metrics derived from the experiment results. The experiment data is supplied by the experiment manager and by the VLE in form of reports or is directly stored in the central database.

The experiment feedback characteristics are stored as well in the central database and are available for further visualization and/or manipulation by the VLE and the others architecture modules.

*Student Guidance Module*

The last module of the GCAR-EAD architecture is responsible for providing student guidance, which means it receives as input the metrics generated by the experiment analysis module and has to determine whether students have achieved the goals defined by tutors/teachers. If not, this module has to indicate learning materials to be reviewed by the students.

### *3.1 VLE integration with Mixed Reality supporting Interchangeable Components*

While the remote access of real laboratory equipment has several advantages, there are also some issues to be considered for teaching control and automation concepts (e.g. the number of students / students groups working simultaneously is equal to the number of physical experiments available; long waiting times caused by slow dynamic systems; and interlocking systems have to be carefully developed in order to avoid that students may damage components via improper actuation).

Two alternatives were identified in order to overcome these drawbacks: (i) use of pre-recorded experiments (ii) use of simulated components.

The use of pre-recorded experiments can be justified due to the fact that it is quite common to have a large group of students having to perform the same assignment within a given time interval. In this case, it becomes quite often that students access to experiment is delayed, even when students would like to execute the experiment with the same initial and working conditions. A possible alternative would be to make students think they would accessing a real experiment and instead of that to send them data from pre-recorded experiments, so that they would have the impression to be running the real plant. While this strategy has some limitations (for example, experiments should have exactly the same initial conditions and parameters could not be modified during experimentation), it would allow a larger number of students to work simultaneously on a single technical plant, therefore reducing the total time interval required by a larger number of students to perform their assignment.

Another alternative is the use of simulated components. Simulations, although sometimes unrealistic, have several advantages that can be explored in different learning scenarios. One of the advantages of using simulations is that they can be easily replicated. Students can then simultaneously use multiple copies (replicas) of the same simulation simultaneously, i.e., identical copies of a simulation model can be executed at the same time by various students. The simulation replicas instead of real experiments do not imply on more equipment. Another advantage of using simulation is that students can speed up slow dynamics systems for quick visualization using simulation models (for instance, while the real process of heating a tank can take hours, the analysis of aspects such as rising time, overshoot, can be done is seconds using simulations. Other positive aspect on the use of simulation models is that they unbreakable. Consequently, safety concerns involving simulation variables limits are not as important as in real experiments.

By analyzing the pros and cons of real vs. simulated experiments, one can see that in some sense they are complementary so that a combination of both possibilities seems interesting. The so called interchangeable components strategy (see Fig. 1) has been developed to allow this combination of both real and virtual components (Schaf and Pereira, 2006). The use of interchangeable components enables the definition of a variety of learning scenarios.

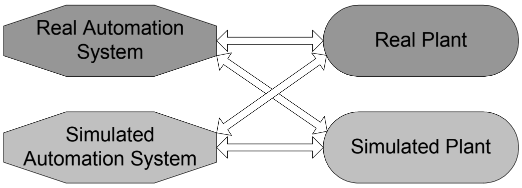


Fig. 1. Interchangeable components strategy.

Based in our experience in teaching control and automation courses, three different learning scenarios can be identified. These scenarios are supported through the use of exchangeable components by combining real and virtual automation systems and technical plants:

*1) Fully simulated*: This kind of experiment setup illustrates an experiment abstraction were simple and ideal simulation models (without perturbations and other real world characteristics) are employed. Although simulation models are not necessarily simple or without perturbations, for didactic issues, the implementation of simple models is more adequate in early stages of experiments learning process. In simplified and ideal models the direct application of the theory concepts is an important issue of this first learning scenario.

Step by step execution can be also implemented since simulated equipments are used and real world constraints are easily manipulated. Since the experiment is purely simulated (virtual) some advantages as models replication can be implemented. Thus, multiple fully simulated learning scenarios can be accessed simultaneously and all experiment data can be easily replicated. Security and accessibility issues like booking systems do not need to be addressed for this scenario.

*2) Mixed simulated/real components scenarios*: This configuration can be used, for instance, in the interaction between a simulated controller and a real plant to elucidate how acquired data from the real plant varies from the ideal model and this can cause instability in the controller programmed logic, consequently, some precautions must be addressed in the simulated equipment to treat that instability. When dealing with a real controller, some problems also occur in the delay of the control logic, since the controller can not process the acquired data instantaneously (commonly, the controller cycle time is responsible for this delay).

*3) Scenario with real components*: This experiment scenario is the typical implementation of remote laboratories were SBBT is implemented and students can perform experimentation using real components and observe how theory applies into practical applications. Here, non-linear behaviour, perturbations, physical constraints, communication delays, etc, affect the experiment and all these “real life limitations” can be visualized. Obviously, this kind of experiment is not so easy replicated and some access control must be addressed, like booking systems, safety concerns, etc.

### *3.2 VLE integration with Tutoring Systems*

The proposed VLE integration with tutoring systems is responsible for every GCAR-EAD interaction feedback. Tutoring systems are dependent to several other tools or modules. Each one of the GCAR-EAD architecture modules stores data in the central database that can contribute to the tutoring system feedback compilation.

Basically an integrated tutoring system gives two kinds of feedback: (i) allows remote experiment configuration according to the user (student) level, *i.e.*, students with no previously recorded interaction with the experiment should start with basic experiments (usually the fully simulated scenario) while more advanced students can directly go to more complex experiments; (ii) infer didactic material according to student performed experiment.

The first type of feedback compilation, searches in the central database only for previously performed experiments and visited learning materials. Based on this data, it “decides” which type of learning scenario the student has granted access. The second feedback type uses besides visited learning materials data also metrics or reports generated by the experiment analyzer to suggest specific didactic material to the student.

The experiment analyzer plays the center role in the experiment-driven tutoring system feedback. There are two proposed types of experiment analyses: (i) for dynamic experiments the result of the analysis (“evaluation”) is mostly computed off-line, that means after the experiment has been concluded control metrics like overshoot and rise time are calculated; (ii) on the other hand, discrete experiment based on logic control can be evaluated in execution time, since the digital I/Os can be tested while the experiment is running. The first type is called pos-runtime- while the other runtime-analysis, but both produces reports that are stored in the central database.

### *3.3 System Implementation*

The GCAR-EAD environment is simply built by several modules represented by functionality and software/hardware modules.

All developed remote experiments (case studies implementations) follow common software architecture with: Apache as Web server software, MySQL as database interface manager; MOODLE as LMS; Elipse SCADA as experiment manager; OPC-DA for experiment level communication interface; and the ISaGRAF as simulation software for all virtual experiments (Schaf and Pereira, 2006).

## 4. RESULTS

All case studies have been successfully applied into undergrad and graduated courses on "Control System Design", "Industrial Automation", "Time Discrete Control", etc. The obtained results have been very positive. In particular, one can see that student's motivation is increased when using remote labs embedded into VLEs and blended learning strategies. Analysis of logging data shows that while some students access the remote experiments (see example in Fig. 2) late at night, others prefer to work early in the morning, that means, each one can define their preferable working time. Therefore the system is being continuously "tested" and improved with lots of students/teachers suggestions.

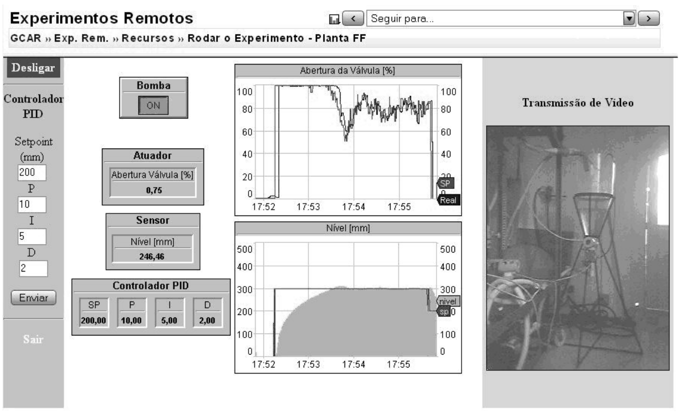


Fig. 2. Snapshot of the remote practice interface of the Foundation Fieldbus Pilot Plant in the GCAR-EAD.

Currently the second class of students is using the blended learning scenario proposed in the course of control theory (undergraduate course in electrical engineering). The system is having excellent results since the interactivity of the students is being recorded and evaluated. A custom quiz was developed to "evaluate" system qualities and faults according the previous class of students. The most meaningful questions of this quiz and the answers are shown in Table 1.

**Table 1. Quiz questions and answers.**

| **What was your impression of the course offered in the GCAR-EAD?** | | | | |
|---|---|---|---|---|
| *Excellent* | *Good* | *Regular* | *Bad* | |
| 48% | 36% | 8% | 8% | |
| **What was your impression of Remote Experiments offered within the GCAR-EAD?** | | | | |
| *Excellent* | *Good* | *Regular* | *Bad* | |
| 50% | 42% | 0% | 8% | |
| **In your opinion which is best for teaching: simulated or real experiments?** | | | | |
| *Simulation* | *Real experiments* | *Both* | *Combination of both* | |
| 0% | 22% | 39% | 39% | |
| **Which of the following characteristic(s) are more important in the GCAR-EAD?** | | | | |
| *Time flexibility* | *Spatial flexibility* | *Integrated learning material* | *Collaborative environment* | *Internet search integration* |
| 70% | 39% | 22% | 57% | 34% |

The performed quiz indicates that the majority of the students accepted the environment and collaborates to the idea of employing simulation and real equipments in the learning process and also combination of both (interchangeable components strategy). The last question indicates that the time flexibility and the collaborative environment are the most important characteristics of the GCAR-EAD according to the students.

The approval rate of the discipline has also increased considerably when confronting the previous semesters with the semester that uses the GCAR-EAD in a blended learning scenario (see Fig. 3). The Last semester had close to 90% approved students, 23% more than the previous semester.

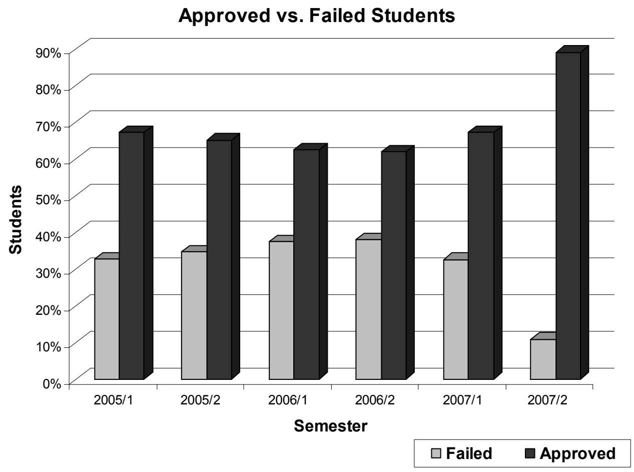


Fig. 3. Approval rate in last semesters.

Despite the high approval rate, the student grades were not affected, *i. e.*, grades did not changed comparing with the previous semesters. The statistics show that grades are affected by the times that students use remote experiments as well as visit the didactic materials of the GCAR-EAD (see Fig.4). Students with "A" grade had close to twice as much virtual environment accesses than students with grade "B".

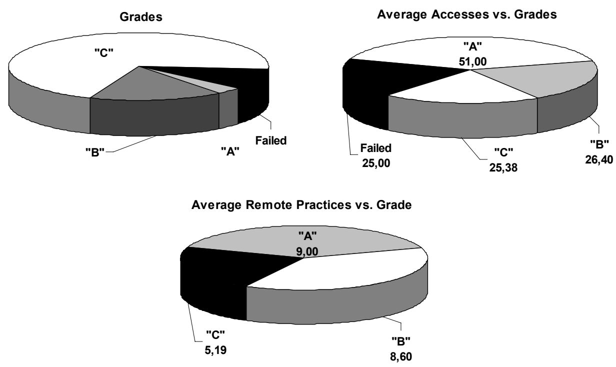


Fig. 4. Blended learning scenario statistics.

## 5. CONCLUSIONS AND FUTURE WORK

It is widely believed that collaborative experiences are powerful drivers of cognitive processes and can significantly enhance learning efficiency. The benefits of collaborative learning are widely researched and advocated throughout literature (Lehtinen, 2003). Regardless of the varying theoretical emphasis in different approaches on collaborative learning (*e.g.* social constructivism), research clearly indicates that in many (not all) cases students learn more effectively through collaborative interaction with others. This motivates to prepare remote labs for collaborative learning (called collaboratories) and to use them in distributed teaching scenarios with simulation tools, hands-on laboratories and practical workshops. Emphasis on collaboration adds new technical requirements to the design of remote laboratories. As a whole, there is a necessity to improve the usability of collaborative remote laboratory tools because otherwise learners may quickly get frustrated and stop working with it.

Although grades does not always reflect the knowledge acquired in the course by students, the statistics have proven that blended learning with remote practice are a simple educational method that increases the approval rate by motivating students with new and state of art technologies employed in engineering education.

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