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

Remote lab: online support and awareness analysis

Christophe Salzmann[1], Denis Gillet[1], Peter Scott[2], Kevin Quick[2]

[1]Ecole Polytechnique Fédérale de Lausanne, Switzerland
(e-mail: christophe.salzmann@epfl.ch, denis.gillet@epfl.ch)
[2]Knowledge Media Institute, The Open University, United Kingdom
(peter.scott@open.ac.uk, kevin.quick@open.ac.uk)

Abstract: This paper presents an initiative for integrating leading edge remote experimentation and synchronous collaboration solutions as a proof of concept to pave the way towards comprehensive learning environments for live interaction, not only between people themselves, but also between people and time-critical online equipments. In this context, a pilot test has been conducted with students from the EPFL enrolled in the automatic control course during the 2007 spring semester to investigate modality, utility, usability and acceptability issues. In such comprehensive environments, awareness plays a very important role to ease interaction and to support learning. This initiative also focuses on investigating advance real-time and embedded awareness features in learning environments.

1. INTRODUCTION

1.1 Interactive online experiment deployment context

Online experiments are typically introduced to complement on-campus laboratory sessions in traditional higher education universities, to avoid travelling to training centres in distance learning or to offer vocational training modules to field engineers. Online experiments are often used in control, robotic and mechatronic education to illustrate theoretical principles and methodologies (Schmid, C. 2003). The comparison between simulations and live experiments results is an important element of the educational methodology (Tzafestas *et all*., 2006).

In terms of human-computer interaction, it is essential to reproduce as much as possible for the distant learner the feeling of being in the actual laboratory facility. In other words, the best possible multimodal interaction and awareness regarding the laboratory equipments and their operating conditions have to be provided so that the drawbacks inherent to the network and the computer mediation are minimized (Salzmann *et all.*, 2007). Hands-on experimentation is a high-level sensorimotor and cognitive activity that is typically carried out in teams and with a significant presence of support personnel with technical and educational profiles. Hence, not only interaction and awareness features related to the online equipments are mandatory, but also advanced collaboration and awareness services supporting the interaction among the learners themselves, as well as between the learners and the tutors. As example, awareness regarding the progress of the class and the other students are essential for sustaining the motivation for learning using online experiments.

The additional flexibility provided by remote connections to online experiments is highly appreciated and permits the students to manage laboratory sessions at their own pace and from their own location. It is also a unique opportunity to develop the necessary and complementary skills for autonomy and teamwork.

After the introduction describing the context and the motivation of this study, the Hexagon and eMersion tools that have been combined to fulfil the requirements for enhanced collaboration and enriched awareness are presented in the sections 2 and 3. In section 4, the scenario of the proof-of-concept trial carried out with bachelor engineering students enrolled in the automatic control course at the Swiss Federal Institute of Technology in Lausanne (EPFL) is detailed. The results of the assessment of the prototype with the chosen pilot group are summarized in Section 5. Finally, envisioned extensions, perspectives and concluding remarks end the documents (Section 6).

1.2 Motivations

As mentioned previously, collaboration services, awareness and tutoring have been recognized as key issues for effectively supporting learning with online experiments. While the eMersion (http://emersion.epfl.ch) environment used to enable remote experimentation using online experiments is fairly comprehensive, only asynchronous collaboration features are available and awareness is not seamlessly displayed in the main environment windows. The Hexagon tool (http://hexagon.open.ac.uk/) was chosen to providing a permanent space for live chat and/or video interaction. The awareness benefit resulting from the visibility of all stakeholders present in the virtual room being indeed considered as a required added-value feature.

To further strengthen the awareness provided by the Hexagon, it was decided to consider the online experiments to be controlled remotely as full participants in the Hexagon room. As a matter of fact, when using online experiments, the availability and the state of these equipments is as important

as the presence and availability of team members from an awareness point of view. From an interaction point of view, the collaboration between team members and the exploitation of the online equipment plays indeed an equivalent role in the knowledge construction and consolidation. Ultimately, the Hexagon room can be considered as a hybrid space providing awareness and interaction features for and between both non-human and human entities. In summary, the prototype has been designed to enable:

- Advanced asynchronous and synchronous collaboration.
- Hybrid awareness related to both non-human and human entities.
- Additional online tutoring support.

2. EMERSION

A comparative study has been carried out to determine the most common features required for completing typical experimentation assignments by students enrolled in the third and fourth year of the engineering curricula at the EPFL. The Web-based learning environment resulting from this comparative study and from student observations contains all the components necessary to complete laboratory assignments successfully. Those components integrated in the so-called eMersion environment are heterogeneous in the sense that they are developed using different technologies and may be located on different servers (Gillet D. *et all,* 2001).

The cockpit-like eMersion environment is a service-based environment that enables the observation and manipulation of real laboratory systems, regardless of the chosen modality (local or remote). In automatic control, the exploration carried out using this environment focuses on experimentation related to the understanding of the dynamic behaviour of mechatronic systems and the design of a digital PID controller.

The environment includes three main parts: the Experimentation Console (Fig. 1, lower left), the Navigation Console (Fig. 1, top), and the Laboratory Journal (Fig. 1, low-right).

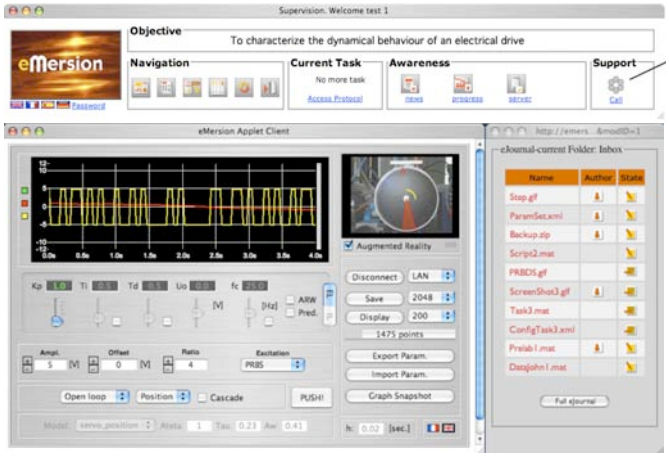

Fig. 1. eMersion Cockpit User Interface.

The Experimentation Console is an interactive Java applet that enables the actual experiments realization, as the result of a remote access to the real equipment. The equipment is visualized in real time using a Web-cam. The applet shown in Fig. 1 is dedicated to the remote observation and the remote control of one of the 22 electrical drives available online at the EPFL. This interface allows users to save measurements, snapshots and configuration parameters in the laboratory journal. Access to experiments offered by other institutions is also possible using the eMersion environment, provided that a dedicated applet is available.

The Laboratory Journal, also called the eJournal, constitutes the asynchronous collaboration part that facilitates reporting, knowledge integration, and sharing. It has been designed as an extended electronic version of the traditional laboratory journal. The eJournal is a collaboration space with a user interface similar to an email client shared by a group of students. The stored 'messages', called fragments or atomic digital assets, can be documents, experimental data, configuration parameters, graphs, etc. All fragments are typed and categorized based on their sources, their content, and possibly the associated task from the predefined experimentation protocol. The eJournal provides various services to manage the fragments. By tracking the fragments creation history, awareness about the group and the class progresses are also generated in real-time and display in the cockpit.

3. HEXAGON

Hexagon is part of a research program on telepresence developed by the Knowledge Media Institute at Open University. Hexagon focuses on issues such as ambient presence awareness and working and learning in public. It is developed using Adobe Flash™ technology and runs within a Web page.

Hexagon users share regularly updated, live, personal Web-cam images, laid out on a grid of hexagons. Features such as a text chat facility and a voice communication mode, allow large groups to interact with each other. Hexagon provides a 'room-based' view of connected participants to specific 'room instances'. Some Hexagon rooms allow guest access, whereby users can enter without registration and can typically remain for a time-limited period with limited functions. Registered 'room users' can send instant text messages to other users individually, or as a group, can have an audio chat with individuals and can look at the "room history" of user attendance. A user's Web-cam image appears as a hexagon, in a grid of other user hexagons (Fig 3). Users can move the hexagons around on this grid, and can zoom in and out on them, and users without a camera appear as grey in the grid. The images are very low refresh with a new frame every 20-30 seconds to not overly taxing a client's personal computer and network. Simple graphical effects are used to indicate to the present community that users interact with each other, e.g. text chat sent from one user to another, is animated by a small spinning 'envelope' graphic moving between the two relevant hexagons.

The Hexagon technology was designed to support ambient awareness in a coherent community. In addition to the idea discussed in this paper, i.e. that in an educational setting groups of tutors and students could mingle in the Hexagon space to make use of the video for convenient opportunistic learning interactions, it could also be useful in a working office context. It is envisaged that remote workers would get an increased sense of community by seeing co-workers and office locations; and that they would use ambient cues to interact more effectively, e.g. to quickly gauge availability, engagement in work on the phone or meetings from video cues. The technology supports a number of work and learning models, from 'student drop-in centre' or 'public helpdesk', to act as a 'jumping off point' for video meetings or other interactions, to a full 'virtual learning space'.

4. INTEGRATION

To fulfil the interaction and awareness requirements previously defined, the Hexagon tool has been integrated within the eMersion environment. It is accessible trough an additional button to launch Hexagon in a separate window (Fig 1. upper right). At login the user has to authenticate within the eMersion environment, the same user identification is used to automatically login within Hexagon room. Other specific users may login within the Hexagon room without using the eMersion authentication.

There are two kinds of specific users in the integrated version of Hexagon, real (human) and non-human. Real users are typically students, teaching assistants or technical support members. Non-human users provide awareness to the Hexagon room members. For example, each of the physical equipments can log within Hexagon room, hence providing awareness about its availability (Fig. 2).

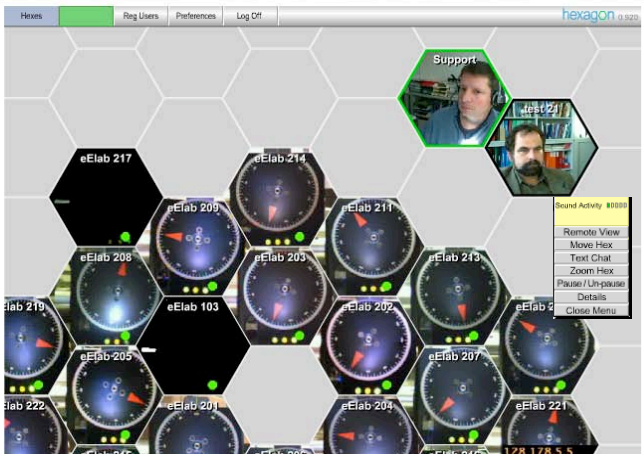

Fig. 2. The Hexagon window with non-human and real users.

The Hexagon room can become quite crowded for real users when the 22 experiments are online. Thus the state of each of the 22 real-time servers has been summarized within a single hexagon as shown in Figure 3. In this figure, a synthetic user –the "Servers" Hexagon– provides, in a compact format, information regarding the proportion of used, operational, and unavailable online experiments. This synthetic view generated by the supervision server that performs dynamical resources allocations frees the Hexagon room from outgrowing number of hexagons representing the real-time servers.

Fig. 3. The Hexagon window with a synthetic user, students, technical and pedagogical support people.

Fig. 3 shows the actual EPFL Hexagon made available for the pilot test described in the next section. The synthetic servers view is mixed with the laboratory participants. It is to notice that beside regular students, specific users providing specific services are available during laboratory sessions. Especially, technical support people and teaching assistants are available.

5. ANALYSIS

5.1 Scenarios

To assess the utility, the usability, and the acceptability of the proposed integrated solution, a pilot test was conducted with 121 students from the EPFL during the 2007 spring semester. The pilot test targeted mandatory laboratory assignments in automatic control offered to students from micro-engineering, electrical engineering, and mechanical engineering during the third year of the traditional full-time bachelor study. They are proposed concurrently with a 56 hours lecture on digital control.

The laboratory assignments in automatic control are structured in three parts: introduction, experimentation, and examination. Special emphasis is given to the freedom offered by the self-directed learning approach and the associated responsibilities in managing personal learning. The experimentation part is split into three two-hour hands-on modules that correspond to the core learning activities. No fixed schedule is imposed on the students; only the sequence of modules has to be followed.

A flexible learning approach is proposed to the students. The idea is that the students can freely choose, to some extent, between a ubiquitous (Web-based) and a traditional (on-campus) access to learning resources and support. In addition to providing supplementary resources and alternative modalities, the choice of the resources and of the modalities is open to the students. As a consequence, the resources and modalities are in competition. The students only select the

resources and modalities that provide a real added value. However, the added value depends strongly on the pedagogical scenarios and learning requirements. The same resource can have a strong added value in one institution and no value whatsoever in another. Hence, acceptability is highly important in the considered framework. Students use the eMersion environment for both local experimentation in the campus laboratory premise (local) or for remote experimentation carried out from home or from another computer room (remote).

The on-campus laboratory premise is accessible on Thursday for two hours according to the students' nominal course schedule. During this session, five teaching assistants are available for face-to-face interaction. An additional on-campus session is also proposed in the laboratory premise during the two hours scheduled according the students' preferences and availability. The main purpose of this additional session managed by one teaching assistant is to provide support for the completion of the laboratory preparation work (prelab). However, it is also possible for students having schedule conflicts and not willing to work remotely to carry out the actual labwork during this session.

The online experiments are available for remote access 24 hours a day, 7 days a week. To avoid access conflicts if local and remote students try to use the same equipment, a dedicated server routes the remote users towards their pre-assigned equipment or the closest available one. Online support is also provided for remote students. One senior student having already taken the course the previous year joins the Hexagon room for two hours from Monday to Thursday according to students' preferences. Even if no support people are present, students can handle their problems in the Hexagon room by chatting with their peers.

In summary, the proposed support to the students of a given study program is articulated as follow for the hand-on local or remote laboratory sessions:

- On-campus labwork sessions: 1 x 2 hours/week.
- Remote labwork sessions: 24 hours / 7 days.
- On-campus prelab sessions: 1 x 2 hours/week.
- Remote prelab sessions: 24 hours / 7 days.
- Evening Hexagon support: 4 x 2 hours/week.
- Continuously via email.

Additional Hexagon presence has been provided at the end of the semester during the lab test period, 5 x 8 hours per week, from 9am to 5pm.

5.2 Utility, usability and acceptability

Four different sources of information have been exploited to assess the utility, usability and the acceptability of the provided online support.

The first sources of information are provided by the 22 online experiment servers that are interfaced at the client side by a Java applet. The experiment real-time servers log in a database user/applet information, such as IP address, login/ logout times and performed actions. The second source of information is provided by the eJournal. It relies on a database to store the fragments information, typically the creation time, the type of fragment, the IP address of the machine used to create the fragments and the user ID. The third source of information is provided by the analysis the Hexagon text chats that have been ongoing during the semester. The fourth source of information is provided by a questionnaire evaluating the online support that has been submitted to all students at the end of the laboratory sessions.

5.3 Real-time servers analysis

During the test period the analysis of the IP addresses stored by the real-time servers showed that out of 1422 accesses to the real time servers, more than one third (37%) were performed from outside the laboratory premise. This ratio clearly shows that the offered possibility to access the experiments from a remote place is widely used. The external accesses proportion is a little bit lower that the result observed in previous years when more than half of the connections were made from outside the laboratory premise. There are two explanations to this observation. First the numbers of available online experiments has been increased from 14 to 22. Second, at the same time the numbers of students has decreased by about 20%. Consequently, more pieces of equipment than necessary were available to accommodate the students attending the on-campus hands-on laboratory sessions.

5.4 eJournal analysis

The database containing the information related to the eJournal fragments showed that out of the 3414 created fragments 86% were created from inside the laboratory. When comparing the above numbers with the numbers extracted from the real-time experiment accesses analysis, it appears that while 37% of the students work with the applet from outside the laboratory, only 14% of the fragments are generated from outside the laboratory. It is to notice that the compulsory number of fragments to be generated via the eJournal has been significantly reduced this semester. Also we previously blocked the possibility to share fragments during the laboratory exams performed at the end of the semester to avoid cheating, resulting in a large exchange of fragments among students the week before the test. This year the eJournal sharing possibility was not blocked during the exam sessions since the questions were generated such that they were all different.

5.5 Hexagon analysis

During the semester the following information regarding the online chats made within Hexagon were recorded: the time, the source name, the recipient name and the transmitted text. The IP addresses were not recorded, thus senders and receivers could not be located. Both the names and the transmitted text were use to identify the chat session, that is

when a chat exchange start and stop. The text was also used to determine the nature of the chat.

The exchange content is categorized in 3 groups:

i) Technical questions such as "how to save some recorded data?"

ii) Theoretical questions such as "which controller should I use?"

iii) Others messages which refer to group testing questions, demonstration exchanges and social exchange chats; these later chats do not involve an assistant.

Both technical and theoretical questions always involved an assistant or a senior student (AE). Students did not use Hexagon to ask questions directly related to the hands-on sessions among themselves. On the other side, students use Hexagon for "social" exchanges among themselves. There was no message sent to the whole community and in only 2 sessions exchanges involved more than 2 persons. Thus Hexagon was principally used as a point-to-point support tool.

Total number of messages	1122	
Number of theoretical messages	457	(41%)
Number of technical messages	354	(32%)
Number of other messages	311	(27%)

The Hexagon analysis shows that outside the regular online support periods from Monday to Thursday, the Hexagon is rarely used.

Figure 4 shows that technical questions are asked at night when the senior student (AE) is online. Three weeks before the exam session at the end of the semester, an assistant was connected continuously during the day. This explains the theoretical exchanges made during the day in addition to the one made at night with the senior student.

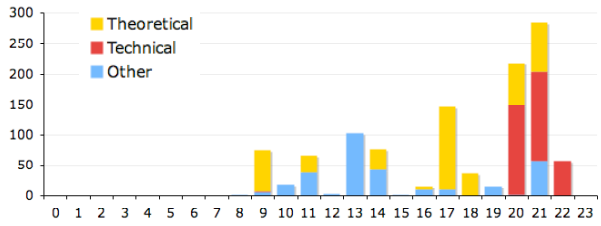

Fig. 4. Hexagon messages distribution during the day (24h).

The numbers of messages exchanges does not reflect the interaction between two users. Thus the messages have been grouped into session, for each session the number of messages has been recorded. Out of the 1122 messages exchanged the following information was extracted:

Number of sessions	134	
Number of theoretical sessions	9	(27%)
Number of technical sessions	14	(32%)
Number of other sessions	111	(83%)

The above numbers of sessions should be put in perspective with the distribution of the number of messages per sessions. The number of messages exchanged for the other sessions is generally very short (1 or 2 messages) while theoretical sessions can contains up to 80 messages.

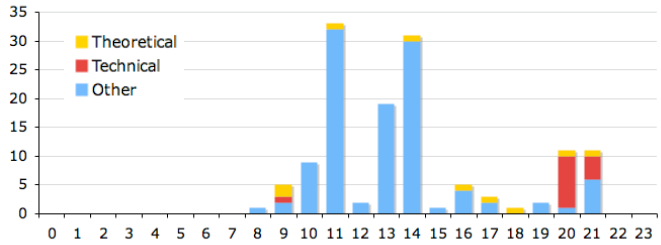

Fig. 5. Hexagon sessions distribution during the day.

Figure 5 confirms the presence of the Hexagon demonstration sessions during the scheduled laboratory session from 10h-11h and 13h-14h. It also shows that technical questions were answered at night when a senior student was online. During the day, technical questions were often answered directly by assistants (face to face interaction). Theoretical questions were answered online during the day only the last three weeks before the exam session. Prior to that period, the students asked theoretical questions directly to the assistants. It is to notice that a significant number of the theoretical questions, approximately 30 %, were asked at the end of the afternoon during the last 3 weeks. This period corresponds to the period identified by the students as a period when they expect online support, see Figure 6.

5.6 Questionnaire

A questionnaire was given to the students to investigate the use and the usefulness of the online support provided by Hexagon tool from a student point of view, 115 questionnaires were returned out of 121. Closed and open questions focussed following elements: i) hardware equipment and network connection, ii) general usefulness of online support, iii) Hexagon related questions, iv) Additional needs and global user satisfaction.

The questionnaires analysis showed that 86 % of the students owned a PC, 3/4 of them are Laptops and almost all of them (94%) are connected to the Internet via an ADSL or equivalent connexion. More than 85% of the students accessed the eMersion environment a least once from outside the laboratory premise. Similarly more than 34% of the students also accessed eMersion environment from their home.

The questions related to online support for the eMersion were to be graded between 1 and 7, the mean being 4.

- Online support is useful? 3.72
- Text-chat is adapted to online support? 3.13
- Voice-chat is adapted to online support? 2.97
- Video-chat is adapted to online support? 2.59
- Hexagon is adapted to online support? 3.58
- I feel comfortable with Hexagon? 3.34

- Hexagon is easy to learn? 4.18
- Support received via Hexagon helped me to perform hands-on laboratory sessions? 2.39
- Time for online support is adequate? 3.85
- Synthetic view (server) in Hexagon room is useful? 4.27
- In general, I'm satisfied with Hexagon? 4.07
- In general, I'm satisfied with online support? 3.63
- Performing hands-on laboratory sessions remotely is useful? 5.70
- In general, I'm satisfied with the eMersion environment for on laboratory sessions? 4.87

The above results show the importance of being able to perform hands-on laboratory sessions remotely but it also shows that the provided online support should be improved. A requested improvement is to have online support active throughout an extended period of time during the day. Figure 6 shows the preferred time for online support. The peak is at the end of regular classes at 5 pm.

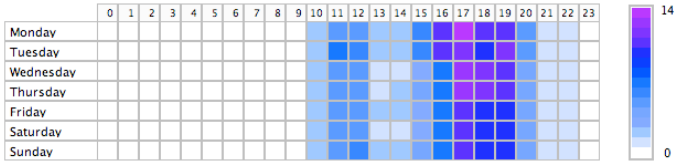

Fig. 6. Preferred time for online support.

The Hexagon acceptance observed in our study is much higher than the ones observed in (Scott *and all*., 2006), where the main complain was "users do not like being visible to the community all the time". The can be explain by the fact that in our context only material and synthetic users providing additional awareness are online all the time, humans being online only after they have connect to the eMersion environment, thus removing the intrusive aspect of Hexagon.

6. CONCLUSIONS

In a move from formal collaborative teamwork to more flexible interaction for high-level learning activities using online experiments, the possibility and the impact of offering a comprehensive Web-based environment have been investigated. This learning environment integrates both asynchronous and synchronous collaboration features, as well as advanced real-time awareness solutions.

The main issue investigated in relation with the deployment of this integrated solution was the possible acceptance of the Hexagon virtual showroom for offering additional online tutoring opportunities and hybrid awareness to the students.

Through a pilot test, it has been shown that students even in traditional academic settings, plebiscite flexible learning opportunities and, as a consequence, need alternative tutoring solutions. This alternative support is highly appreciated if available online typically between 5 and 7pm, i.e. after the regular classes but before the students leave the campus to get home (there are no on-campus dormitories at the EPFL).

One of the key issues raised during the pilot test was indeed the acceptability of new technologies enhanced learning solutions in a context where the time for appropriation and for the actual exploitation is reduced to a minimum. Only tools with very high added values, quick getting started time, or already known by the students are accepted. As a consequence, the asynchronous collaboration tool (eJournal) was mainly used for the storage of the digital assets related to the online experiments and the synchronous one (Hexagon) to get environment awareness and quick answers before the laboratory exam period. The students actually used the time they spend together on campus to discuss their activities face-to-face, either with peers or when teaching assistants are available. These remarks and the results given in Section 5 have to be taken carefully, as the learning scenario strongly impacts the usage of the technologies provided. So, no general conclusions can be drawn. However, they can be use as indicators to issue recommendations for future successful deployments.

Especially, it is clear that the overall acceptability of the environment can be improved by integrating tools used regularly by the students. For example, it is now envisioned to enable the tutor and the students to automatically generated audio or video podcasts from interesting discussions held in Hexagon with just one click. These live Q&A resources will then be directly available to students via iTunes or subscribed feeds without the need to move in a special space to get them.

Also, a better integration between the awareness additions and the actual interaction practices is envisioned. It should be possible to click on the hexagon of an online experiment to directly initiate an interactive remote experimentation session. This addition would turns the Hexagon awareness view as the new access portal for the online laboratory facility; again reducing the number of tools and Web places to visit for completing laboratory assignments.

REFERENCES

Gillet D. and G. Fakas. (2001), eMersion: A New Paradigm for Web-Based Training in Mechanical Engineering Education. *International Conference on Engineering Education*, Oslo, Norway, August 2001, pp. 10-14

Salzmann, C., Gillet D., Mülhaupt, P. (2007), End-to-end adaptation mechanism for remote experimentation, *ACM Personal and Ubiquitous Computing - Special Issue on "Ubiquitous e-Learning Solutions over Heterogeneous Networks"*, Springer, in press

Schmid, C., (2003) Remote Experimentation in Control Engineering, *Proc. 11th Mediterranean Conf. on Control and Automation* MED'03, Rhodos, pp. IV12-01

Scott, P., Quick, K., Tomadaki, E., Linney, J., (2006) Ambient Video Awareness: "It's Great, but I Still Don't Want It". Workshop: What went wrong with Technology Enhanced Learning, *European Conference of Technology Enhanced Learning*, Crete, Greece.

Tzafestas, C.S., Palaiologou, N., Alifragis, M., (2006) Virtual and Remote Robotic Laboratory: Comparative Experimental Evaluation, *IEEE Transactions on Education*, **vol. 49, no. 3**, p.360-369.