Migrating Learn-by-doing Engineering Curricula to Blended Learning

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Abstract: Our institution trains highly skilled engineers in the field of information and communication sciences and technologies. Due to a geographical relocation on two separate sites, it needed to integrate distant learning in its curricula. This migration to a blended learning environment was made through several simulation-based lessons developed by us within the framework of a European project. In order to induce the student-learner to initiate an active and constructive distant learning process, our on-line lessons are integrated into a collaborative learning platform. This article aims at describing our approach to guarantee the quality of our Web-based education system and at presenting a course which was recently reengineered for purposes of blended learning, followed by quantified feedbacks from students and teacher's validations.

1. Introduction

Our institution is a French "Grande Ecole" with a clear focus on the industrial and professional world. It trains high quality engineers in the field of science, information technologies and communication technologies, with over 200 graduates per year. Since several years, our engineering curriculum relies on the project-based learning scheme (cf. Rouvrais et al. 04b). Pursuant to this approach, theoretical knowledge in an engineering curriculum is not sufficient; technical and non-technical skills are also needed (see ABET[?] 04). An active participation of the students in their learning process is therefore requested, whether through on site or distant learning. In 2003, our institution was converted to the European credit transfer system (ECTS). Combined with our geographic organization (i.e., our institution is located on two separate sites), this conversion requested us to integrate distant learning in our curriculum and to migrate our pedagogical schemes into a blended environment. In this context, we wondered how we could use ICT (Information and Communication Technologies) in order to induce the student to initiate an active and constructive learning process for scientific disciplines in such blended learning model.

In order to guarantee our outstanding learning quality with a clear skills' orientation, we believed that the introduction of ICT had necessarily to be combined with a structured pedagogical study. We observed that the integration of distant learning in a curriculum often implied a reengineering of such curriculum. In particular, we noted that such integration was made easier if based on basic, reusable, and adaptable learning objects. Also, we noted that different learning activities had to be integrated and their content varied so as to motivate the students. The conclusion of our study led us to integrate real interactive simulations as part of the learning process for know how to do. Accordingly, within the framework of a three-year European project, we developed several reusable simulation-based lessons for learn by doing. These lessons were proposed in an adaptable pedagogical canvas so as to enable their encapsulation in different pedagogical schemes for distant learning (Gilliot & Rouvrais 04). This article will actually present, as an example, an eighty-hour course development relying on our simulation-based lessons which has been fully integrated into our curriculum at B.Sc. level.

This article is structured as follows: in section 2, we will justify the skills and competency requirements for engineering curricula before presenting our problem and project-based learning schemes. Section 3 will clarify our institutional requirements for creating a blended learning environment. Section 4 will expose our previous developments on a polymorph pedagogical canvas for on-line simulation-based lessons and will present a course example recently reengineered for purposes of blended learning. Quantified feedbacks from students and teachers' validation are given in section 5. Finally, our conclusion will address our ongoing investigations on distant learning.

2. Foundations of an Engineering Curriculum

Engineering curricula should offer an access to the theoretical knowledge and related know how which will constitute the grounds of the future professional activities of the students. But this is not sufficient. First, engineers continuously face changes during their career, e.g. new information are discovered or new technologies emerge in connection with certain disciplines. The scientific curriculum cannot obviously cover the whole knowledge corpus which will be necessary for the graduate-engineer. Therefore, engineering institutions should ensure that their curricula also develop their students' autonomy and increase their self-training abilities. For that, students should have ways to update their knowledge and learn new information by themselves. Second, student should also be able to establish clear links among all the disciplines studied in their curricula to perceive adequately the interactions among the various fields of engineering. Third, the emerging engineer will also need non-technical skills. His/her career will benefit from personal abilities such as communication, oral and written presentation skills, leadership, creativity, ethics, team spirit, cooperation, etc. Those abilities are more and more associated with competences in the engineering domains (e.g., scientific and technical competences, design competences, inter and intrapersonal competences, cf. Lachiver & Tardif 02). In the widely shared opinion of Moore & Voltmer (03): " An engineering education should prepare students, i.e., emerging engineers, to use a problem-solving process that synergistically combines creativity and imagination with rigor and disciplines". In order to start implementing this extensive conception which will best develop all the above skills, a general engineering curriculum should therefore include various types of learning practices, such as :

- ?? courses dedicated to delivering knowledge content,
- ?? practical work (PW) sessions aiming at enhancing the know-how needed,
- ?? projects conceived for developing design competences, as well as inter and intrapersonal competences.

Depending on the educational paradigm favored by the institution (Joyce, Weil, & Calhoun 03), the sequence of activities may vary. Pursuant to a traditional pedagogical scheme, ex-cathedra courses (i.e., lecture) will come before practical work sessions, and projects will aim at providing a synthesis (cf. Fig. 1, left). In project-based learning schemes (PBL), which can be seen as long-term problems (Savery et al. 96), students are conducted to develop theories and solutions around large practical problems, most often in group (cf. Fig. 1, right). The pedagogical system developed by our institution is more and more oriented toward this second scheme.

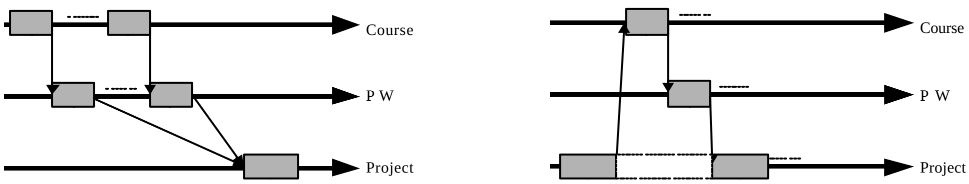

Figure 1: (left) classical scheme **(right)** an instance of project-based learning scheme

Before migrating parts of our curriculum to a blended environment, we ensured that, whether based on a instructive or constructivist scheme, it could be decomposed into basic learning activities (e.g., lecture blocks, practical work units, and projects). From this observation, we derived the following characteristics:

1. Distant ex-cathedra lessons should be based on teleconferencing tools so as to permit the lecturer to give his/her lesson while remaining in contact with his class. Those distant lessons should also be associated with a repository containing documents as well as an online forum for questions;
2. Practical work units should be built around an access to a remote laboratory (cf. Casini et al. 03, Gilliot et al. 01); or to simulations focused on pedagogical objectives (Gilliot & Rouvrais 04). Support by a teacher or an assistant may be ensured through classical tools such as email or chat bo xes;
3. Project work should be supported by additional collaborative tools enabling meetings, exchange of information and sharing of documents by the different members of the project group.

Most of the tools associated with these activities are now provided by Learning Management System (LMS). The following section examines the way our institution actually created a blended learning environment in accordance with the above mentioned characteristics.

3. Institutional Requirements for a Blended Learning Environment

Our institution is located on two distant sites: the headquarter is located in Brest, that is 250 kilometers from Rennes where a separate branch has been set up for historical reasons. In 2003, it reformed its curriculum to give its students the opportunity to create their own curriculum by selecting "Major" and "Minor" semester optional courses. This change meant an increasing number of lessons to be given, within the same time-frame, to smaller groups of students. This reform implied more traveling duties for teachers among sites. Facing more financial and time losses as well as less appropriate working conditions, teachers were eager to improve their time schedule, while maintaining quality. Consequently, they approached distant learning with an open mind and were even quite progressive in their conception of distant learning tools. Before proceeding with any operational deployment, a test period was carried out with a view to make sure that both teachers and students would consider the solutions proposed as pedagogically valid. In particular, comments from the teachers and students were analyzed in order to enhance the training quality of the distant learning services. Based on these results, three services were proposed to develop distant learning:

1. The teleconferencing tool: the audio-visual signal from the teacher is sent to the distant monitor of the lecture theatre in parallel with the multimedia presentation on the central screen. The lecturer can either meet his/her students or use teleconferencing. When distant learning is necessary for a module composed of several lessons, the first one is nevertheless always in class, face to face, on site;
2. Real interactive simulations: during practical work sessions, distant teacher/supervisor may communicate *via* Internet in order to help and monitor student practices (e.g., synchronous, asynchronous);
3. Virtual classes: students and their teacher/tutor may communicate, exchange exercises and documents, give back contributions and assignments, carry out team work, etc.

Thus, since early 2004, we deliver practical lessons on-line through a LMS. This has allowed our institution to greatly improved its dual-location constraints. For example, a practical lesson including sixty to seventy students, requires three rooms and three teaching assistants when taught face to face. In a blended learning environment, on-line practical lessons reduce the number of teaching assistants who have to travel. One single expert may monitor, help and assist his/her distant students. Similarly, the access to the school halls by the students is limited by the internal regulation. Thanks to distant learning, students may carry out their practical work assignments or self training, either individually or, if they wish, with a partner, from any computer (e.g., dormitory, home). This possibility thus reduce constraints relating to time or location. The following section is dedicated to the simulation-based lessons developed which permits, among other things, to ensure the quality of our distant practical work session.

4. Simulation-based Learning Objects and Course Design Example

Too often, despite the development of promising technologic tools, the integration of on-line resources in courses has minimum impact as regards training and learning know-how. In order to be really beneficial, the access to information must be combined with an active participation of the learner. The on-line learning process is clearly improved by the use of real dynamic simulations (Feldstein 03), with the possibility for the users to change behaviors through parameters modification (e.g., variation of speed, pausing, data entries, zooming on results). In engineering curricula, these simulations include for example experimentation, demonstration of properties, validation of theoretical concepts, depiction of phenomena. Thus, the use of interactive simulations could enhance our students' knowledge and expertise and increase their autonomy (in particular, through self-validation of their knowledge and know-how acquisition), as emphasized in PBL schemes. Also, thanks to the on-line simulation-based style, learners could assign some certitude degrees to their knowledge and skills, developing as such more control and autonomy. For these reasons, simulations have become the founding stones of our on-line model. During a three-year European project (INVOCOM http://www.invocom.et.put.poznan.pl), with other European, we have developed a large repository of simulation software to be used for on-line courses (from a technical standpoint, our simulations are implemented mostly as complex Java? applets (Rouvrais et al. 04a)).

But simulations are not sufficient per se. We kept in mind that these simulations should have a pedagogical objective and should include precise questions and exercises requesting some thinking. In light of this, our simulations are integrated in lessons composed, among other things, of reminders, self-assessment exercises, manipulations, glossary and feedbacks. The exercises and problems we use in our simulations often include an assistance aiming at conducting, dynamically, the learner to answers. For reusability into different pedagogical schemes, we integrate our on-line simulations into a pedagogical canvas (Gilliot & Rouvrais 04). Overall, our lessons are self-contained objects, supporting composition with other lessons. Our approach simply favors a pedagogical polymorphism which may, by nature, satisfy the professors concerned in the specification of the courses.

Since September 2004, following a few months dedicated to testing and validation, the eighty-hour telephony RES530 course has migrated into a blended learning environment through the Moodle LMS (Dougiamas & Taylor 03). The services of this LMS enable a follow up and tutoring of the students through synchronous (e.g., chat) and asynchronous (e.g., forum, mail) communication mediums. Traditional lectures are delivered through video-conference by a teacher located in Rennes to students located in Brest. Proper transition from declarative knowledge to practice is given to this course. Apart from projects, the related learn by doing and simulation-based lessons last nine hours spread over two weeks. Figure 2 below presents a part screen-shot of this practical lessons. This part is based on three practical work lessons taken from our repository of simulation-based-learning objects. For each of them, an instance of the pedagogical canvas is synthesized so as to respect the pedagogical requirements of the expert teacher. The simulation-based learning objects are externally adapted by a questionnaire defined by the teacher. Each question represents an operational task and all of them allow to achieve the final task. Students set the different simulators with parameters given by the teacher and record their answers after having observed, analyzed and interpreted the corresponding results. The expected outcome is a deliverable on the practical work to be sent through the platform by each student or group, by a fixed deadline. Collaborations and assistance is provided by the teacher *via* questions and answers recorded in the LMS forum and progressively build up a complementary pedagogical resource.

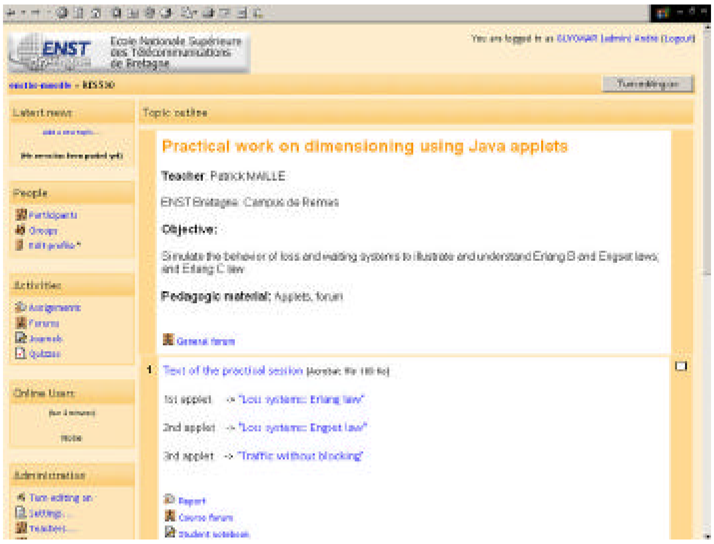

Figure 2: Moodle access page to the RES530 practical works.

5. Usage Feedback and Pedagogical Efficiency

The use of a distant learning platform allows a temporal and geographic flexibility. Our LMS permits an administrator to identify actions carried out by students during their connections. It also enables to estimate the periods of activity of a particular student, and we noticed activities outside scheduled periods (e.g. night). Overall, these activity reports demonstrate that working practices can greatly differ from one student to another.

Usability from the Student Point of View

At the end of the second 2004 semester, students were asked to give their opinions about the practical work lessons. Those opinions were to be filled in on-line. The valuation criteria used were elaborated with our partner institutions on the INVOCOM European project. The range of possible answers for criteria was as follows: “insufficient, reasonable, good, very good”. The results below show that the experience was quite well perceived by the students:

?? As regards the platform in general, 78% of the answering students found the application “good” or “very good”, and 84% considered that the use of this methodology was beneficial for their academic/professional training. For this first session, we have not explained to the students how to use the distant learning platform in order to assess its conviviality. Still, we keep in mind that the targeted audience has a serious ICT background;

?? A majority of students found the application easy to use, with an intuitive navigation and a good presentation of the material;

?? Acquisition of new knowledge was more mitigated: 53% found it “reasonable” and 31% “good” or “very good”. This probably stems from the fact that the theoretical notions used had already been treated in lecturers (consolidate knowledge through the observation of a system behavior over time);

?? About 50% of the answering students evaluated the capacity of the application to motivate the trainee as “good” or “very good”. This may be due to the fact that some students are not well used to working autonomously and the presence of a teacher increases their motivation;

?? The teacher was connected to the discussion forum. This interactivity was perceived positively by 81% of the students with answers like “good” or “very good”.

Accordingly, this training evaluation by the students highlights that the distant learning experience has been globally well perceived by the students who considered it as an interesting and flexible way of learning (e.g. being able to work according to their own rhythm, obtain answers to their sent questions, read questions asked by other students and the answers given).

Pedagogical Efficiency from Teachers Point of View

The teachers assess the level of consolidation and acquisition of knowledge through the questions asked by the students in the discussion forum, and through the reports delivered by the students at the end of the session. According to the teachers’ assessment, the use of a communication forum is definitely a very good pedagogical method, for the following reasons:

?? the forum allows to answer the students’ questions both during and after the practical session. to maintain a good interactivity, the teacher must reply as soon as possible during the session. The asynchronous forum may increase the pedagogical efficiency as it induces the teacher to take some time to write a complete and precise response, which may not be possible if a chat system was used;

?? students have to formulate clearly their questions, around simulations and knowledge elements, which is sometimes sufficient for them to have a better view of the problem raised. In terms of knowledge, a teacher review has concluded that most of the student questions were particularly relevant, since they were related to the crucial points of comprehension. Moreover, these questions appeared only once on the forum, which indicates that all students who wanted an explanation found it by simply consulting the relevant reply on the forum. This communication method is particularly efficient in the context of a practical work session.

Still to assess the pedagogical value of the blended course, the teachers also reviewed the reports (including the students’ answers to the practical work lessons) which were uploaded by the students through the LMS. In doing so, the teachers wanted to evaluate the students’ comprehension of the concepts and problems addressed during the practical work session. Their conclusions are as follows:

?? the basic notions used in the practical session are known by all the students; the simulator has helped them in understanding the role of all the major parameters integrated in the system studied;

?? the material used has also permitted to describe the various models existing for the system studied during the session; hence, the students have realized the essential differences between those systems through the three simulators;

?? the students have perceived the importance of assumptions and understood that simulations are sometimes the only way of predicting the performance of a telephony system. For instance, students have observed that the theoretical results did not hold when some assumptions were not verified.

6. Conclusion

Too often, despite the development of promising technologic tools, the integration of on-line resources into engineering curricula has minimum impact with respect to know-how and skills. Students should participate actively through a genuine commitment to their learning process. Particularly in engineering studies, constant interactions between theory and practical ski lls (i.e., know-how and know-how to do) are necessary. Based on that, we believe that simulations must be the milestones of our on-line materials. Also, considering that the introduction of distant learning may be progressive and vary in time, we think that distant learning materials must be conceived so as to be reusable in the future, or at least, so as to be modifiable very easily and in a cost-effective manner. For all these reasons, our simulation-based lessons are integrated in a constructivist pedago gical framework, as a support for blended learning and personal work and our pedagogical canvas, based on simulations, greatly favors reusability.

As of today, our approach concerning the introduction of distant learning in our engineering curricula has proved quite beneficial. The distant learning application presented in this paper enabled to reach the objective of cost reduction as concerns teachers' missions. Moreover, it cancelled both time and geographic constraints for the students, and proved to have a good pedagogical efficiency. For the next session that will be carried out during spring 2005, a short introduction specifying the software needed to run the Java? applets will be added to the platform, in order to solve connections problems reported by a few students connected from outside the campus. After this first experience conducted between the two distant sites of our institution, we are planning to use the Moodle platform for distant learning to be used with other institutions located in foreign countries. For instance, in the framework of our collaboration with ITAM, the Mexican Technological Institute, we will display our practical work session with traffic simulators and give access to other pedagogical material during Autumn 2005.

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