INTRODUCING FLEXIBILITY IN TRADITIONAL ENGINEERING EDUCATION BY PROVIDING DEDICATED ON-LINE EXPERIMENTATION AND TUTORING RESOURCES

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Abstract — *The Swiss Federal Institute of Technology in Lausanne (EPFL) is deploying a flexible learning scheme for selected pilot courses in engineering education. In such a scheme, the pilot courses combine traditional lectures and written exercises with additional Web-based learning resources. The main objective of this initiative is to sustain the evolution from traditional teaching to autonomous learning and to better integrate the increasing number of educational resources available on-line. In engineering education, a key activity to improve the learning process is hands-on experimentation carried out using either simulation tools or laboratory facilities. This paper describes how Web-based experimentation resources have been introduced at EPFL to provide more flexibility to students enrolled in an automatic control laboratory course. The changes in the way the tutoring has been organized are also presented along with the evaluation results obtained after two years of deployment.*

Index Terms ¾ Flexible education, Web-based learning environment, hands-on experimentation, on-line tutoring, pedagogical evaluation.

1. INTRODUCTION

With the trend initiated by MIT to provide free access to on-demand lectures, the identity and the reputation of academic institutions will probably depend in the near future on their ability to accredit both in-house and on-line educational content integrated in innovative curricula as well as on their ability to offer dedicated student support in transforming traditional education into a rewarding learning adventure. The typical on-line content that today mostly includes on-demand lectures and electronic documents will henceforward be considered equivalent to classical textbooks. When considering engineering education in such a framework, the potential added value that can be brought in student support comes especially from the availability of **resources for carrying out hands-on experimentation** [1] and from **tutors for sustaining the learning process**.

Anticipating this challenging evolution, the School of Engineering at the Swiss Federal Institute of Technology in Lausanne (EPFL) started in 2000 a multidisciplinary effort to provide students with Web-based experimentation resources that can be exploited in an autonomous and flexible way. The tutoring scheme has been adapted concurrently to comply with this new experimentation paradigm. The first experimentation modules accessible in a flexible way were deployed in the framework of an automatic control laboratory course during the academic year 2001-2002. Students tried out these modules with the aid of a Web-based training environment called “the cockpit” [2]. This name is related to the submarine metaphor that was chosen in designing the user interface. This e-learning environment (the cockpit of the submarine) enables knowledge immersion and provides tools to actively interact with the field of exploration.

In the case of the automatic control laboratory course, the environment enables the observation and the remote manipulation of real mechatronic systems such as an electrical drive and an inverted pendulum. The exploration focuses on experimentation related to the understanding of the dynamical behavior of mechatronic systems and the practice of the different stages that must be completed in the design cycle of a digital controller. As a matter of fact, the environment is mainly dedicated to sustaining knowledge reinforcement and know-how acquisition rather than content delivery.

It is important to emphasize that the same cockpit can be used either on the campus laboratory premises or at a distance to experiment with either in-house or external experimentation facilities. The envisioned scenario for the next years is the following: first to have students getting used to the laboratory experiments on-campus, then carrying out remote experimentation on the same setups at a convenient time and from location of their choosing, and then finally accessing alternative setups shared on-line by partner universities to enrich the offer of available resources.

After this introduction, Section 2 provides more insight into flexible learning and its peculiarities in the EPFL context. Section 3 describes the pedagogical scenarios that enable a more flexible learning scheme that sustain hands-on experimentation. Section 4 presents the pedagogical evaluation carried out to assess the efficiency of these proposed scenarios. The results of this assessment are

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analyzed in Section 5. The paper ends with concluding remarks.

2. FLEXIBLE LEARNING

Flexible learning corresponds to a diversification of the pedagogical methods by using new learning technologies in a traditional education framework. It deals with alternative tutoring types, interaction styles, time and workplace situations, as well as cognitive activities (concepts learning, exploration, problem solving). It also allows these methods to be easily adapted to various educational contexts and customized to various students' profiles.

Flexible learning aids the students in achieving better personal organization, in taking greater responsibility in the management of the learning activities, in enabling greater latitude in the choice of the learning places, in integrating customized resources, and in rethinking relationships to learning. For the teacher flexible learning involves adapting various training strategies to the students' skills, sharing workload between human and computer, allowing more tutors' availability to meet students' expectations, providing flexible schedules, enabling various mediation types according to the students' needs (tutoring, guidance, mentoring), increasing experimentation possibilities, and training more students.

Hands-on experimentation is essential to sustaining the learning process. The intellectual effort required to analyze and understand phenomena, to take actions and to evaluate errors, effectively develops the students' knowledge and know-how. It enables students to learn how to investigate, analyze and achieve scientific and technical objectives in the real world. In addition, experimentation encourages the students to enhance their initiatives, their creativity and their own methodology of work. A flexible learning approach is the key to successful hands-on hands experimentation [3] activities. Enabling Web-based access to experimentation modules gives more freedom (and responsibility) to students to choose the most suitable time to carry out their revising or deepening activities.

Introducing flexible learning in a traditional academic institution such as EPFL is not an easy task. First of all, there is already a well-established offer of mandatory and elective courses. Hence, flexible learning can be integrated mainly in existing courses, which requires an adaptation of both the pedagogical scenarios and the technical resources. Due to the necessity of carefully assessing any improvement before going further in the renovation process (students have already a comparison point with existing courses), the additional features are introduced progressively every term. Secondly, the renovation process initiated at the EPFL relies on the project-based scheme with limited funding, therefore only few courses can be adapted at a time to integrate flexible learning approach and resources. Hence, numerous other courses proposed in the curricula are still taught the traditional way according to fixed schedules. This hinders students' possibilities to entirely manage their time and benefit from the new offered flexibility. Finally, another difficulty is the fact that regular EPFL students are accustomed to learn in a quite passive and assisted way, which means with a low required level of autonomy. However, autonomy is a prerequisite in flexible learning. Therefore particular attention must to be taken to sustain the development of students' autonomy with both dedicated activities and adequate tutoring. Indeed, autonomy does not mean to work alone, but rather to know how to adapt oneself to various learning situations, to know how to learn and to discover one's own way of learning, to know how to work with others and to learn from others, and to know how to organize oneself.

3. PEDAGOGICAL SCENARIOS FOR REMOTE HANDS-ON EXPERIMENTATION

The use of new learning technologies implied some changes in pedagogical methods such as: the structure, presentation and, organization of information (clear objectives, pertinent information, precise stages); the management of location and time (combined solutions with office hours and on-line support); and the development of flexible and distributed tutoring (shared roles between students, teaching assistants and educators) aiming towards students' autonomy.

Pedagogical scenarios that take all the previously mentioned elements into consideration have been established. All the experimentation modules include two successive stages: the *prelab* and the *labwork* assignments. The prelab assignments do not require access to the experimentation facility, however they must be completed prior to beginning the labwork. This prepares the students for the labwork with reminder questions that necessitate a comprehension of the related theory and with technical questions that necessitate an elaboration of adequate solutions to enable further operations to be carried out during the labwork.

To facilitate students' transition from their usual assisted learning to a flexible one, the tutoring has been distributed between office hours and on-line support. Three periods of office hours have been opened to allow the students to ask questions or to submit their prelab assignments to a teaching assistant. The on-line support has been provided either by asynchronous tools such as e-mail and forum or by synchronous ones such as the telephone.

An initial scenario was implemented from October to December 2001 with a pilot group of students from mechanical engineering. The focus was primarily on deploying the distributed support scheme and secondarily on introducing the Web-based experimentation environment. A distinction was made between semi-flexible and flexible sessions. In semi-flexible sessions, the students worked either with Web-based experimentation resources or on-line tutoring resources. In flexible sessions they used both resources. A typical session for mechanical engineering students lasted for 4 hours, which corresponds to the time needed to carry out two hands-on experimentation modules. The sequence of the proposed hands-on experimentation sessions and their respective mode of deployment were the following: (i) One semi-flexible session to introduce the Web-based experimentation environment. The students carried out their labwork on campus using the Web-based experimentation environment in presence of a teaching assistant. (ii) One flexible experimentation session to develop to students' autonomy. (iii) One semi-flexible experimentation session to exploit the online tutoring scheme: The students carried out their labwork on campus using the real laboratory facilities without the presence of a teaching assistant. (iv) Two traditional sessions, due to the unavailability of remote access to the necessary laboratory resources at that period. (v) One laboratory test organized on a fixed date to assess the students' knowledge and know-how acquisition. This consisted of a final collaborative labwork assignment and an oral presentation of their work.

An improved scenario was implemented from March to June 2002 with a pilot group of students from micro-engineering (a special study program at EPFL). The focus was primarily on reinforcing flexibility and secondarily on introducing support for sustaining autonomy acquisition. A typical session for micro-engineering students lasted for 2 hours. The sequence of the proposed hands-on experimentation sessions and their respective mode of deployment were the following: (i) One semi-flexible session on campus to introduce the Web-based experimentation environment. (ii) One round table discussion with students to evaluate their working methods in a flexible setting and their responsibilities associated with increased autonomy. Indeed, the majority of the students did not necessarily organize and manage their working time. However, the use of a Web-based training environment requires particular working methods, especially when there are many problems involved in the technicality of the support in addition to the learning of the subject matter. (iii) Two flexible sessions for the last modules. No weekly deadlines were imposed. Students had only to respect the prelab-labwork assignment sequence. A FAQ (Frequently Asked Questions) was also created to sustain students with recurring problems. (iv) One laboratory test, which was scheduled freely by the students within a three-week period.

4. PEDAGOGICAL EVALUATION

A preliminary assessment carried out in the traditional setting was taken as a base of comparison for the subsequent scenarios. In order to obtain a reaction from the students regarding distance support, in the preliminary session the element of distance was modeled by asking the teaching assistant to leave the laboratory premise and to only answer questions by phone. This model revealed the following problems that were resolved before implementing the initial flexible scenario: (i) The risk of cognitive overload (too many problems to handle simultaneously) was solved by optimizing the duration and the content of the experimentation modules, by adding a well-designed introductory session before the experimentation sessions, and by setting up a technical help desk. (ii) The need for regular feedback in a situation where near help is privileged was solved by expanding the office hours and by spreading them along the weekdays. (iii) The lack of ability for self-evaluation was partially solved by adding some questions about the students' own answers and by allowing the students to request feedback on partially completed prelab assignments.

The effectiveness of the scenarios mentioned in Section 3 was evaluated with the objective of assessing the impacts of changes regarding the tutoring schemes and the new learning methods.

The evaluation was carried out with mechanical engineering and micro-engineering students by using questionnaires, observation grids, and collective interviews. Both pilot groups (mechanical engineering and micro-engineering) were divided into two samples. The reference sample carried out the experimentation in a traditional way and the flexible sample carried it out in a flexible way. The support staff was composed of the technical, pedagogical, and teaching assistants.

In order to avoid a potential bias due to differing levels of computer literacy, a questionnaire was distributed at the beginning of the evaluation to estimate the students' ability to work with computers.

Observations of the manner in which students were using the Web-based environment were carried out during the semi-flexible sessions to identify possible adaptations of this environment. The observations focused on activities such as comprehension and analysis, search, data management, and collaboration. The observation tasks were delegated among four observers, with each one following one type of activity. Finally, at the end of the experimentation sessions, a debriefing meeting was organized to evaluate students' difficulties and degree of satisfaction. They also had the opportunity to make proposals for improvement. The members of the support staff were present and available for answering their questions. Discussions were also held with the teaching assistants to get their point of view concerning the tutoring situation.

5. ANALYSIS

The analysis focused in particular on the collaboration between peers (the students work by peer), the interactions between assistants and students (on campus or on-line), the processes of learning using a Web-based environment, and the grading scheme.

- **Collaboration between peers:** The absence of the teaching assistant in some semi-flexible sessions brought an added value to the collaboration between students. One could indeed remark that when the teaching assistant was not present in the laboratory, the peers interacted with other peers to find an expert, substitute for the assistant, thus turning students into tutors.

- **The interaction between assistants and students:** The students sometimes worked by themselves, and sometimes with the remote assistant or the assistant in charge of office hours.

  When the students wished to interact with the tutors, they could use asynchronous tools such as e-mail and forum. In this way, the students could receive corrections of their work. Some students used the telephone to receive a more immediate feedback.

  The forum was a failure because it did not correspond to the students' needs. On the other hand, they used a functionality of the Web environment called the *laboratory journal* [4] as a communication tool to interact with the assistants. This might explain part of the failure of the forum.

  The students faced difficulties with both the innovation of the environment and with the subject matter. Some mentioned problems related to the availability of the assistants. However, on-line interactions between students and teaching assistants are valuable because the elaboration of questions is already an active learning approach. Some students were astonished to discover that, even from a distance, the assistants could adequately meet their needs.

- **The processes of learning:** It can be difficult to formulate questions using communication tools, even if the interaction possibilities are widened in such a way. The students can put their questions in writing or by pose them by telephone, which leads them to reflect more on their questions and how to formulate them, and therefore they sometimes find the answers without assistance. In this manner, the students can develop auto-evaluation skills.

  The interactivity of the Web-based environment induces the students to perform more experiments and tests. They discover that they are entitled to make errors and that they will not be sanctioned for doing so. Experimentation gives them the opportunity to carry out a real training. Another significant advantage of interactivity related to experimentation is the possibility to repeat the experiments until they are fully understood.

- **Grading scheme:** The grading scheme has been adapted to comply with the constraints of flexible learning. Especially, the teaching assistants are no longer in charge of the grading. Only one of the teaching assistants is in charge of checking the completion of the labwork assignments (progress evaluation). The actual grading (normative evaluation) is completed during the laboratory test and handled by the instructor. The other teaching assistants provide support (formative evaluation).

6. CONCLUDING REMARKS

In general, the students consider the Web-based learning environment valuable, mainly because of its flexibility that allows managing one's workload over a long period of time. This is not the case in the traditional framework in which all students have to carry out the same work simultaneously. Hands-on experimentation is also very advantageous, according to them, because they consider it essential to practice in real-world conditions.

The students' answers collected during the debriefing meetings showed that the most important thing was to manage their time, as they want, despite the constraint imposed by other courses. However they do not really profit from the added flexibility. In fact, students from the flexible sample completed their final labwork at the same time as the traditional sample group. A close analysis has shows that this occurred because these students were working on a very time-consuming project for another course and, consequently, they used the flexibility provided in the automatic control laboratory course to release their overall workload.

Further work is being carried out to provide immediate and synchronous feedback [5], because students enrolled in flexible experimentation activities are looking for quasi-immediate analysis of any blocking problems that they may encounter. This is the reason why some students still prefer to work in a rigid framework with a teaching assistant at their disposition instead of a Web-based environment, in spite of the advantages of flexibility.

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