Enhancement of Geomatics Education by Using Internet Based Techniques

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SUMMARY

The Swiss Federal Institute of Technology in Lausanne (EPFL) has introduced the Moodle Learning Management System (LMS) in 2005. Since, the number of teachers and users has increased rapidly. With more than 350 active courses hosted on Moodle for this autumn semester, its utility is not to be demonstrated anymore. In 2006, the Geodetic Engineering Laboratory (TOPO) has introduced its on-line undergraduate topography course, with more than 26 000 connections during the last semester for 160 students.

In accordance with EPFL's guidelines (E-Learning Strategy[1])[1], and with the support of the Funding Programme for Teaching and Learning, TOPO has developed an e-learning platform, fully integrated into a LMS, for the first course in geomatics. The motivation behind this is to move from teaching and learning in a traditional way to a more interactive way: personalized exercises are completed by students on the Internet and are automatically corrected with help facilities. This concept of e-learning, called *Exomatic*, stimulates the students to be more autonomous in their learning of, and training in, topographic data processing and analysis.

The main module of *Exomatic* is composed of the generation of Internet-based exercises, the presentation of personalized data in a smart user interface, a collection of answers in HTML form, automated corrections and a smart calculator with graphical hints provided by Geogebra. The system provides evaluations for students and statistical feedback for the teacher on student performance and progress. The objective is to improve the autonomy of students and to facilitate the preparation and corrections of exercises for teachers and assistants. *Exomatic* is a standard Moodle module, and can potentially be shared by a wider community. This paper presents the structure of the programme and its integration into the course content. Its implementation in the LMS and a first assessment by the students are presented.

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[1] http://craft.epfl.ch/webdav/site/craft/shared/learntech/StrategieTechnologiesFormation-2007.pdf

TS 6G - e-Learning I
Pierre-Yves, Gillieron, Switzerland
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Enhancement of Geomatics Education by Using Internet Based Techniques

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1/15

Enhancement of Geomatics Education by Using
Internet Based Techniques

1. INTRODUCTION

The Swiss Federal Institute of Technology (EPFL) offers complete study programs leading to Bachelor, Master and PhD degrees in 6 faculties. The School of Architecture, Civil and Environment Engineering is one of them where the Geodetic Engineering Laboratory (TOPO) is a research unit traditionally involved in teaching topography, geodesy and navigation technology. These disciplines comprise a large part of mathematics (linear algebra, geometry, and statistics), computer science, as well as the optics and mechanics needed for understanding of the surveying instruments. Teaching the basics of geomatics to 180 students requires an important time investment to present the theory, to introduce and correct the exercises and to demonstrate the surveying instruments. To successfully disseminate the knowledge, it is essential to have an up-to-date learning environment.

The development in information and communication technologies (ICT) offers a lot of possibilities and tools for the enhancement of classical teaching methods. The EPFL has introduced e-learning strategy with the Funding Program for Teaching and Learning (FIFO) for the projects which aim at developing teaching resources and educational scenarios. In this context, TOPO has decided to submit a proposal for the development of an e-learning platform for the fundamental course in geomatics, called *Exomatic*. The goal of this project is the full integration of the exercises into the Learning Management System (LMS) Moodle. TOPO has introduced and developed on-line exercises by its own initiative since 2005 (Gilliéron, 2006), and is ready to improve these resources within an attractive e-learning environment. Moodle [2] was progressively introduced at EPFL since the summer semester 2005 and its deployment has increased very fast as shown in the figure 1. The LMS is currently hosting over 659 courses, with an average of 1500 visits per day during the semester.
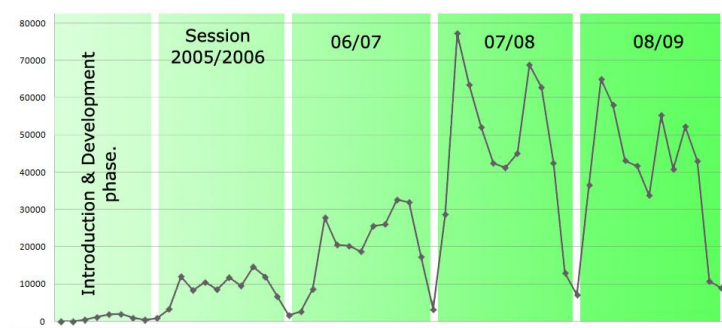

Fig.1: Monthly visits to Moodle since 2005.

Pierre-Yves, Gillieron, Switzerland
Professional Education – e-Learning - content development methods, tools, student support.
Enhancement of Geomatics Education by Using Internet Based Techniques

The LMS has been used by the teaching staff for implementing several resources: presentation (slide show), quiz, videos and some exercises. The fundamental course in geomatics is mainly composed of topography and calculus exercises. The first collection of on-line exercises, introduced in 2005, was evaluated by the students with a list of remarks and propositions. Computer security, help, self-correction mechanisms, and finally the graphical visualization were the main items proposed by the users to enhance this type of exercise training. This valuable feedback and the evolution of e-learning technologies have encouraged the teaching staff to improve the on-line exercises as an alternative to its traditional classroom-based teaching methods.

The development of *Exomatic* supported by EPFL through the FIFO Program has started in September 2008. Introduced during the spring semester 2009 with a better integration between the different resources of the course, this project aimed at encouraging the students to be more autonomous during their training.

The teaching staff has introduced learning technologies melting into a beam of educational tools, integrated within many other pedagogical activities orchestrated for the basic course called "fundamentals of geomatics" (EG). Because e-Learning methods are expected to play an increasing role in professional education there is a growing need for knowledge transfer. In this context *Exomatic* could also be shared in a near future with other educational programs.

2. FUNDAMENTALS OF GEOMATICS AT EPFL

2.1 Geomatic curriculum at the institute

Both curricula in Environmental and Civil Engineering propose a track in geomatics to the students at the bachelor level. These basic courses include the following topics:
-year 1: fundamentals in geomatics
-year 2: Quantitative methods (Statistics, adjustment, calculus, numerical problems); Geodetic engineering (geometrical problems in the context of topography, field work with surveying instruments); photo interpretation (basic knowledge of photogrammetry, practice in the field with aerial images)
-year 3: Geographic Information Systems (basic knowledge of GIS and database, representation of spatial data, acquisition and exchange of data, conceptual modelling); Satellite based positioning (geodetic references, basic knowledge of GPS, measurements and GPS data processing, architectures and evolution of GNSS systems); remote sensing (electromagnetic waves, passive and active sensing, basic of image analysis)

3rd	G I S	Remote sensing	Satellites based positioning
2nd	Quantitative methods	Geodetic engineering	Photo interpretation
1st	Fundamentals in geomatics		

Fig.2: Fundamentals of Geomatics in bachelor programme at EPFL.

2.2 Presentation of the course EG

The students of the first-year class from civil and environmental engineering sections have to attend to the basic course in geomatics. The program launched a curriculum that provides an introduction in GIS, the fundamentals of geodesy, the principles of geomatics and the surveying techniques. As shown in figure 3, the recent fusion in 2004 has tripled the number of students with about 180 persons during the last semester. The vertical axis represents the number of students and the horizontal one represents the different sessions. Moreover, the total number of students has increased since the last three years which is encouraging.
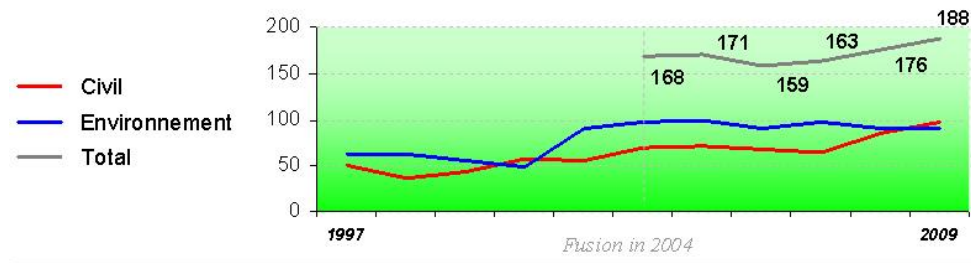

Fig.3: Number of students taking part to the basic course in geomatics since 1997.

The traditional teaching in this branch requires a significant time investment due to the organization of exercises and practical work. From the first year, the EPFL students have access to e-learning resources, which facilitates the approach to the courses. This is a current trend in Open and Distance Learning (ODL) systems developments showing interesting innovations (Cardoso, 2005). The use of the new technologies was obvious in our case before starting the development of a comprehensive course for all the participants. This has allowed to reduce the mobilization of teaching staff and to give the skills to the students for a better independent learning.
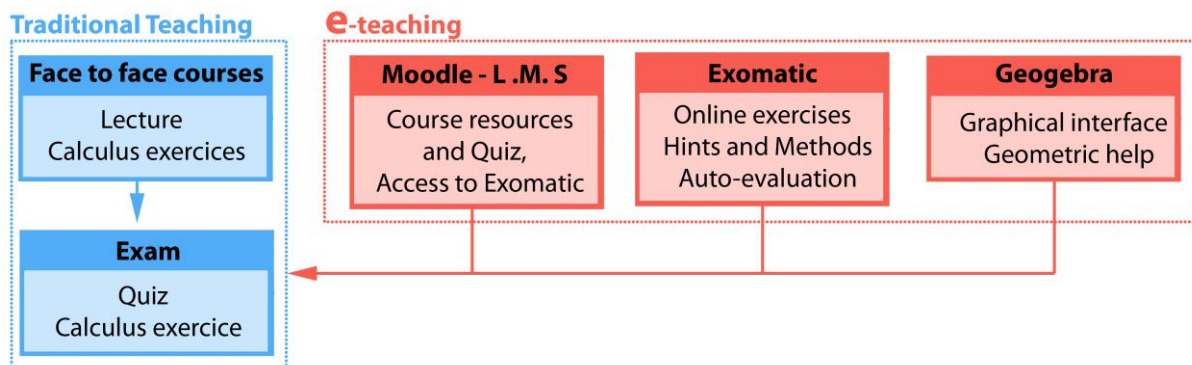

Fig.4: Structure of the course.

The structure of the courses was divided in two parts last semester as shown in the Figure 4:
- Traditional teaching with the lecture and exercise in face to face hours followed by the exam;
- E-teaching part with the Web-based LMS for an easy access to the learning content.

The courses balance between face to face lectures followed by individual exercises. This domain comprises a large part of mathematics calculus (linear algebra, geometry), and the need for the knowledge of the surveying instruments. These types of exercises help the learners to autonomously master the concepts seen during the lecture. All the teaching staff is present during the presentation of those exercises to assist and answer the students' questions, but it is clearly impossible to assist all of them.

Above all, the introduction of e-learning in geomatics is based on personalized exercises. Traditional lessons remain, although the focus is now on non-formal learning via different on-line resources provided by the LMS. With this approach, real persons can be associated with the e-learning environment which is accepted when it is supported by a direct contact (Platteaux, 2004). For a student, the insertion of on-line educative resources in such a context is reassuring. Simultaneously it offers the teacher an opportunity to elaborate interactive courses. The teaching staff uses essentially the LMS interface to deliver content of the courses and to assess learning steps using quizzes and lessons. These solutions were well accepted by the students with a large participation as shown in figure 5 and the results of the course evaluation have demonstrated the high level of approval (see section 4).
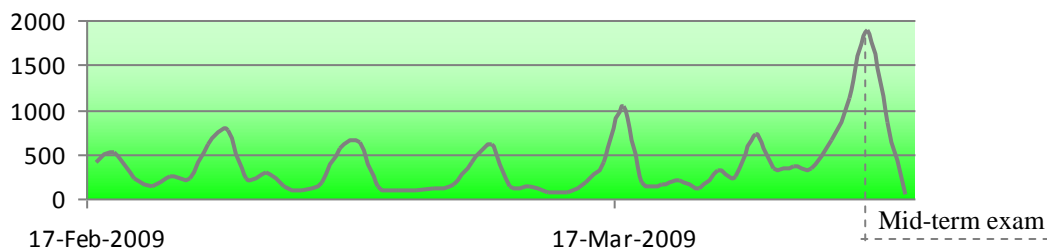

Fig.5: Number of connections to the geomatic LMS during the semester.

Each rise represents the number of students connected on the LMS after the weekly ex-cathedra course. What is notable is the highest peak reaching about 2000 logins, which shows the great number of users before the mid-term exam. This schema demonstrates that the LMS is closely coupled with the content of the lectures.

2.3 Motivation

Four main reasons have triggered this project:

- The development of innovative resources for teaching the fundamentals in geomatics,
- The improvement of e-learning tools with a focus on calculus exercises
- Saving in the man power during the teaching correction work,
- The increase of student's autonomy in learning geomatic and its exercises.

TS 6G - e-Learning I   5/15
Pierre-Yves, Gillieron, Switzerland
Professional Education – e-Learning - content development methods, tools, student support.
Enhancement of Geomatics Education by Using Internet Based Techniques

.FIG Congress 2010
Facing the Challenges – Building the Capacity
Sydney, Australia, 11-16 April 2010

The few hours of contact, and the important part of the exercises for the comprehension of the courses were the principal motivation for us to think about integrating on-line exercises and assessment in the curriculum of the geomatic courses. Moodle offers large possibilities for managing resources and activities, but due to the specificity of the exercises (calculus, geometry and data processing), the LMS is not efficient enough to propose interactive exercises. After a brief state of the art on web-based exercises in geomatics, we have decided to develop and to implement our own on-line exercises. Different reasons have motivated this choice:

– Firstly, the cost and the complexity of professional software solutions and the difficulty of interfacing them with the LMS.
– Secondly we wanted a personalized application to include the current geomatic exercises on dynamic web pages.
– Finally, we wanted to improve the experience of the first version of *Exomatic* and to adapt it to the e-learning environment of the EPFL.

In summary, Moodle is the basic component of the e-learning and is accepted very well by both the teachers and the students. Therefore, the development of particular exercises in topography is still a challenge and can be received better by the students when they are fully integrated into the LMS.

3. DEVELOPMENT AND IMPLEMENTATION OF EXOMATIC

3.1 Overview

In concrete terms, *Exomatic* provides pedagogical material to solve exercises via a user-friendly interface that stimulates the students' involvement and allows them to prepare exercises before the exams. The access to the web-based exercise is secured by a control service which provides a unique login procedure to the different web pages of the EPFL which simplifies the management. To perform the visual effects we have used the EPFL graphic chart and its cascading style sheets. Moreover attractive illustrations, videos, personalized data, interactive graphics and the fact of addressing students by their first name create a catchy environment that is visible publicly via any web browser.

Conceived as a cross-platform application, the program automates the production and marking of individualized exercises. It is a collection of interactive procedures which are connected simultaneously to a user interface and to a database. Summarized in figure 6, the following section describes its global concept.
1. First of all, the teaching staff creates dynamically the exercises data.
2. Once connected to the web pages, the student is able to read the reminder of the exercise and its related instructions. One can see their own session data on the basis of their name, the program save automatically this information on a student's profile data base.
3. The data of the exercise are generated by a random function that provides specific numerical values to each student. All the set of data is transmitted directly to the user interface

and displayed with the possibility to control at the end of the exercise the validity and the correctness of the answers.

4. Once the process is solved, the student's answers are transferred in an html form.

5. These responses are integrated into the student's database via the server.

6. In case of bad numerical values or false responses, the program performs a warning and proposes to restart the exercises, keeping the student's initial values on the different forms.

7. The automation of the exercise correction is given by the comparison of the student' values with the exact responses stored into the exercise database. The evaluation of the results is done by taking a certain level of tolerance into account. Three classes of evaluation are proposed: (i) accurate, (ii) with a small error and (iii) out of tolerance (large error) depending on the results sent by the student, its evaluation and the predefined level of tolerance. The results and the feedback are automatically presented and a simple click on an icon allows the user to access on hints and advices for a better comprehension of the error committed.

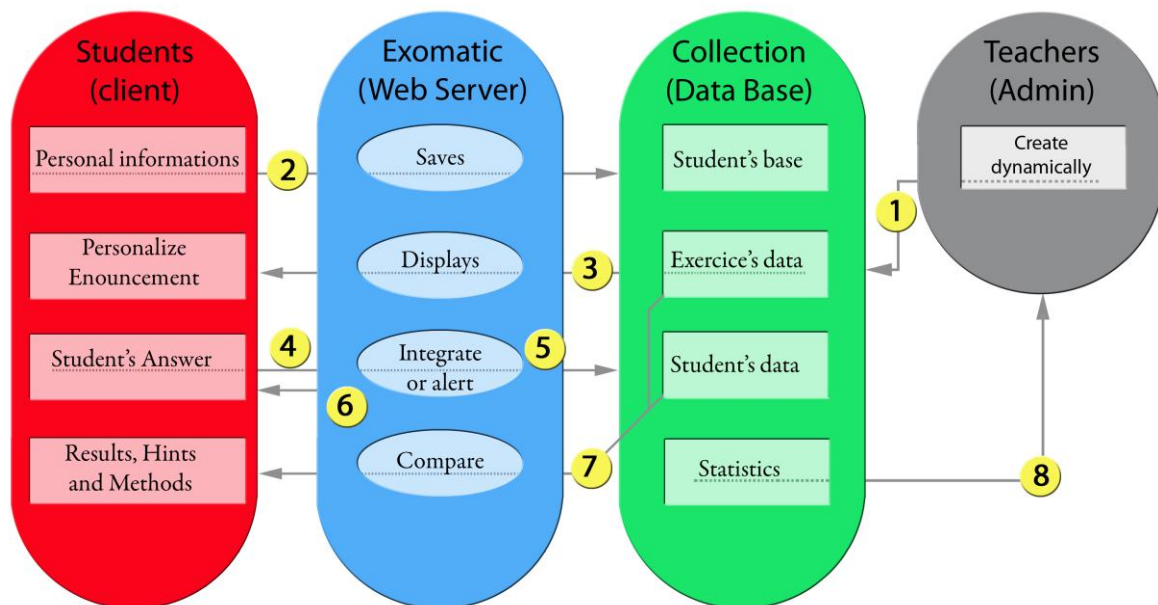8. Statistics are available for the teachers.

Fig.6: Semantic structure of *Exomatic*

The system provides exercises, results, help and evaluations for the students and statistical feedback for the teacher on student's performance and their progress. The administrator part of *Exomatic* proposes already a set of management tools for the elaboration of exercises and other more specific functions for statistical analysis (success rate) and also the possibility to assess the students. This specific management page allows the teaching staff to identify the typical difficulties in answering some questions. With this kind of information the teacher can point out some part of the exercise and explain the calculus process more thoroughly during the next lecture.

3.2   Choice of the informatics designs

The development phase is performed by a small team working together with the teacher. This good cooperation between both parties has a great advantage because of the availability of real teaching condition. The students have also been involved in the evaluation of the second version of *Exomatic*. This quantitative and qualitative assessment of the on-line resources was a fruitful feedback for the developers and for the next implementation. This section will present the different programming languages and software technologies chosen for the elaboration and the development of the project.

3.2.1   Server and data collection

We have installed the software package called WAMP [3]. This is a web-server application which allows us to create our own web application dedicated to the e-learning in geomatics with the main following components: Apache, PHP and the MySQL database.

–   Apache is available for a wide variety of operating systems. It allows us to develop in a local host with a Windows server and to exchange easily the data with the other servers of EPFL, in particular with Linux.
–   PHP or Hypertext Pre-processor is a scripting language designed for the web development and for the programming of dynamic web pages. PHP allows us to communicate with the server and makes a link between the database and the collected responses sent by the students.
–   MySQL is a relational database management system used to store a collection of data linked to the exercises (solutions included), to the student's answers, to the evaluation of the results and finally to statistical values. This database provides also a multi-user access to the exercises.
–   PHPMyAdmin is used to create and manage our databases.

The *Exomatic* web pages are hosted by EPFL server for security reasons and better performance. While 160 students are connected simultaneously with the database, the server must have enough power for the processing of several requests and must provide the selected exercises to the users promptly.

3.2.2   Personalized calculator

JavaScript is used in the web forms proposed to the users. This programming language is implemented as an integrated component of every web browser, which allows the development of enhanced user's interface with dynamic functions (e.g. calculators). This technology enables the development of a specific calculator which contains the main functions for solving the exercises. This concept is integrated in the chain of e-learning after the first attempt of the students. If they send bad responses, these specific calculators allows the students to understand the process step by step. This scripting language is combined with a PHP procedure to perform a "calculator pop-up" regarding the values allocated to the student during the session. The graphical Application Programming Interface (API) for the output of dynamic figures is also based on JavaScript.

3.2.3   Dynamic graphical hints

Pierre-Yves, Gillieron, Switzerland
Professional Education – e-Learning - content development methods, tools, student support.
Enhancement of Geomatics Education by Using Internet Based Techniques

.FIG Congress 2010
Facing the Challenges – Building the Capacity
Sydney, Australia, 11-16 April 2010

The Students' understanding seems to be influenced by the use of figures and well adapted representations of the problem, described by Darien in 1994. Moreover it is because of the lack of graphic hints (proposition of the students after the first evaluation), that we have integrated a graphic mode for helping the students.

After a brief state-of-the-art on web dynamic representation, we have selected the application GeoGebra [4] which is well adapted to the configuration of *Exomatic* and to the references of EPFL for the development of e-learning. GeoGebra is a free and a powerful set of functions for graphical views: e.g. the algorithms used in topography and the graphical representation of the main parameters like angles and distances (figure 7).
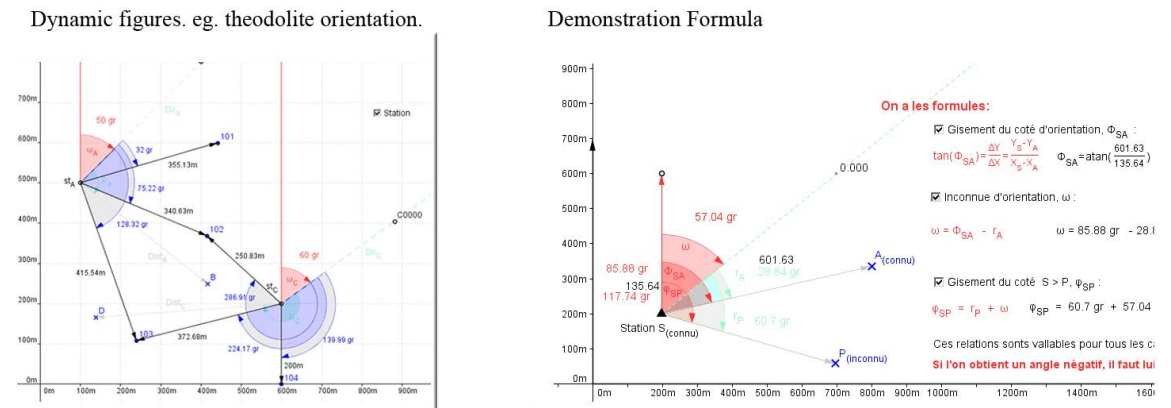

Fig.7: Example of GeoGebra graphic representation

Laureate of the prestigious Tech Awards 2009, GeoGebra is dynamic software for mathematics gathering arithmetic, geometry, algebra and calculus. It is an interactive set of geometrical functions allows us to construct the basic exercises presented during the course with points, vectors, segments, lines, and angles. The main advantage of GeoGebra is the possibility for the user to change dynamically the values directly on the figure. An expression in the algebra view corresponds to an object in the graphic view and vice versa. *Exomatic* is providing this graphic interface as a complement to the exercise and as a help associated to the training process. With this interface the student can directly compare his own graphical representation with the solution on the web. GeoGebra has the ability to deal with the JavaScript language and the different functions and parameters. The exercise data are extracted from the MySQL database and are dynamically managed by PHP and JavaScript for the construction of the graphical corrections, which can be compared with the student's values. On the same way the student's answers are used to build the graphical results. Visual comparison allows a better understanding of the possible errors or the assessment of the precision. A filter is already available for the integration of the GeoGebra API in the Moodle pages.

In sumary, *Exomatic* uses the PHP language combined with a MySQL database to personalize the data dynamically and output corrections immediately, in

nt development methods, tools, student support.
sing Internet Based Techniques

association with Geogebra for graphical representations. The JavaScript language is also used for the different helps and calculators. It is a stack of components associated and organized to enhance the learning via basic exercises.

Fig.8: Exomatic's components

Pedagogical activities and dynamic resources have to be orchestrated in a common learning environment like Moodle to improve the learning. In this second version, a link between both learning environments is still necessary. However, the next version will integrate all the technical components of *Exomatic* (Figure 8) directly into the LMS.

3.3   Implementation in Moodle

The last evaluation of *Exomatic* (see section 4) has demonstrated the good acceptance of these on-line exercises by the students. Therefore, the teaching staff will logically continue this project with the integration of the project as a new module of the LMS. This will facilitate the access to this type of resource for the teaching community. The aim is, firstly, to build and exchange catalogues of exercises with the other partners, and, secondly, to share it as a standard Moodle module with a wider community. Due to the growing use of Moodle in the teaching community, it was necessary to integrate the development of *Exomatic* into Moodle and to take advantage from the great number of functions offered by the LMS. We would like to implement it in the next version of the learning platform.

Moodle developers, also called Moodelers, have already proposed a wiki where all the indications are given to construct a personalized module [5]. Moodle is programmed under the language PHP with an object driven approach, and with MySQL database for the data storage. All the technical instructions are provided for the programming of modules which will be shared with the community and integrated into the LMS. Tables, functions and names of variables have to correspond to construction mode of all the other modules. Respecting these rules is essential for an acceptable integration of *Exomatic*. Moodle is a GNU license, which allows people to access to the source code for the implementation of other modules. We will soon propose an environment of development for this specific module, which will encourage interested teaching staff or developers to contribute to this project.

This possibility of sharing resources will have a positive impact on the evolution and the enhancement of the project. With a future integration into Moodle, *Exomatic* will access to other modules and benefit from other functionalities (e.g. grades, assignments…). Students will automatically integrate these exercises like a normal and continuous part of their in-line geomatic course. For the teachers, the reports and the evaluations provided by the LMS are useful for the administration of the course, and for fixing problems or detecting failures of learning (Jancsó, 2008).

4.   PEDAGOGICAL RESULTS

Pierre-Yves, Gillieron, Switzerland
Professional Education – e-Learning - content development methods, tools, student support.
Enhancement of Geomatics Education by Using Internet Based Techniques

The development of e-learning resources is obviously based on a close collaboration between the teaching staff and the students. For this reason we have focused on the provision of a preliminary version of *Exomatic* to the student as soon as possible with the goal to obtain feedback. This first assessment is essential to orient the future progress.

4.1 Trials during the semester and assessment

More than a hundred students have participated in the *Exomatic* project to prepare their exams. The evaluation of progress in the quizzes and exercises shows a linear improvement between the students' first and latest attempts. All these resources were not mandatory, but strongly encouraged by the teaching staff in preparation for the exam consisting logically in the same type of questions and calculus.

A survey was elaborated in collaboration with the students and proposed at the end of semester providing a range of information on the acceptance of the technology. One of the objectives of the Centre for Research and Support of Training and its Technologies (CRAFT) is to evaluate courses at the teachers' request [6].

More than two thirds of the class have filled the questionnaire out and individually evaluated the course in general, the on-line resources, and finally the Exomatic.

4.2 Analysis of the results

The Figure 9 shows the perception of the resources introduced during the semester: first the Moodle management system and the quizzes, and then the *Exomatic* project.
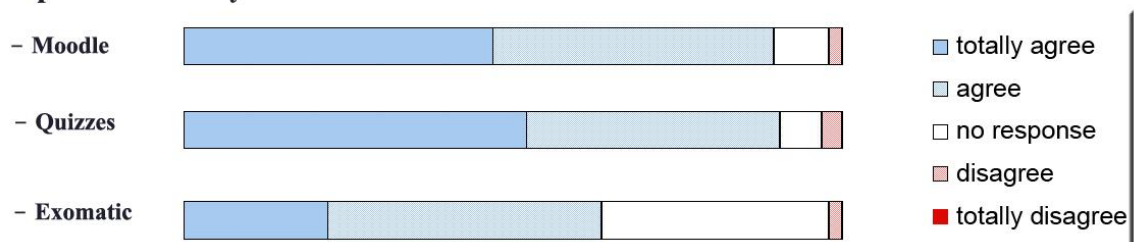

Fig.9: Learning and training resources appreciation

First of all we can notice a relative uniformity of the students' answers. The course via Moodle is well evaluated with more than 80% of favourable opinions. However, this global analysis seems reassuring and reflects a positive acceptation from the students, for whom this computer-based approach represents no major difficulty. The result for the acceptance of the learning management system is very encouraging for the teaching staff who proposed a set of quizzes and resources after each face to face lecture.

The second part of the graphic, related to the *Exomatic*, shows a large percentage of no response. This means that some students have not used the on-line exercises because they were introduced late and shortly before the first exam. Only motivated students have used them for their personal training before the exam. However, *Exomatic* exercises are well

accepted by this group of students with a small percentage of disagreement. This positive sign of acceptance of *Exomatic* is very promising for future development of e-learning tools, especially for the exercises of calculus. The students have the possibility to formulate comments and suggestions.

The student's observations are predominantly positive but this is probably due to the variety and the combination of different activities: face to face lectures and exercises, handouts, quiz and *Exomatic*. All these resources are perceived as useful by the students. There are some weaknesses too, regarding the tedious calculation exercises and the lack of clarity of certain statements (quiz) although the automated correction is weakly decried by 5 % of the students. This means that the feedback provided to the users has to be illustrated better in order to understand the reason for a false response. These remarks are interesting because they suppose more investment in the preparation of resources. This good acceptance of the new learning technologies for the geomatics course encourage us to carry on the development of the project while evolving with the expectations of the users (students) and within the e-learning strategy of EPFL (Deshogues et al, 2009).

The CRAFT has appreciated the variety of methods and resources made available to the students to learn this discipline and the clarity of the course and materials. Beyond this finding, the CRAFT proposes some specific improvement for the geomatic courses.

Firstly, they recommend to check the various feedbacks generated by the learning resource: Exomatic and quizzes, to perform them for a better learning interface. Secondly, by integrating the different part of the course and establishing complete scenario, they have proposed to improve the link between the course content, the exercises and the quizzes.

On the whole, the assessment of the students combined with the interpretation of the CRAFT remains stimulating for the teaching staff and the educational investment was deemed appropriate.

5. CONCLUSION AND FUTURE WORK

5.1 Full automated corrections

The second phase of the project has already started, consisting in the full implementation of Exomatic within the geomatics course. After the first trial and assessment of this new learning system we are improving its functionalities (see section 3) for its introduction in the next semester. One of the goals of the next version is the adaptation of exercises with a new set of tools for calculus. In 2009 Exomatic was introduced late and only few students took this opportunity for training themselves before the exam. The introduction of on-line exercises to complement the face-to-face session will allow the students to improve their understanding of the concepts. The aim of this development is to reduce the time between the distribution of a new homework and its correction. Until now students received a new exercise and the correction was available only after one week. Bringing corrections automatically within the

Exomatic process will be a source of motivation because students are able to monitor their progress in quasi real-time.

For the teaching staff, the full implementation of these exercises will allow a better monitoring and detection of the gaps in knowledge, which will induce a targeted teaching: e.g. specific explanations about misunderstood algorithms during the next lecture.

5.2 Powerful graphical representation

Geomatics is a discipline where graphical outputs play a key role for the interpretation of data related with the spatial environment. The improvement of *Exomatic* with a graphic tool like Geogebra is a clear advantage for the representation of topographic sketches and for data like coordinates, angles and distances. The students will benefit immediately of this tool during their training exercises: detecting error in calculus as soon as possible with graphical means will have a positive impact on their progress.

5.3 Dissemination of Exomatic

An important perspective for the project is to exchange resources with other schools or institutes involved in geomatics education. This could be possible with a co-operative system (e.g. Moodle) which allows sharing common resources in a standard format: e.g. a common library of exercises specialized in geomatics. This new tool is specialised and applicable to mathematically and geometrically based subjects. We want to propose a smart interface to share our program with other interested teaching staff. The release of the *Exomatic* code under a Moodle module is a way of publishing this web-based training and, if possible, to federate the interests in such an approach. The use of convenient tools and targeted objectives on the exercises has proven to be a sustainable solution for implementing on-line exercises. Nowadays, learning technologies take an important role in education. They are becoming an unnoticeable part of pedagogical interventions (Dillenbourg, 2008).

5.4 Conclusion

The growing number of students in civil and environmental engineering has a positive effect on the search for new teaching methods and is a factor of motivation for an introduction to geomatics based on e-learning. From the beginning of the project, the teaching staff has taken the students' needs into account and has solicited feedback at each important step of the development. This close collaboration has proven that the level of acceptance is better when the design of the program can evolve within the context of teaching.

This new step of development with the inclusion of smart help and new tools like dynamic calculus and graphic interface will increase the autonomy of students. They will be capable to generate their own data for each exercise and to understand the relationship between the calculus and its graphical context. It should not be forgotten that *Exomatic* is a complement to the face-to-face course. It is absolutely not envisaged to develop a global concept of web-based learning, only a better integration between the course content and the exercises is planned.

TS 6G - e-Learning I   13/15
Pierre-Yves, Gillieron, Switzerland
Professional Education – e-Learning - content development methods, tools, student support.
Enhancement of Geomatics Education by Using Internet Based Techniques

.FIG Congress 2010
Facing the Challenges – Building the Capacity
Sydney, Australia, 11-16 April 2010

The introduction of the LMS and on-line training is well accepted by the students. The assessment of the course has provided a series of remarks which are useful for the current step of the development. The other fact is that the students are quickly autonomous when carrying out their exercises. This is a positive sign for this pedagogical approach, a promising path that has to be followed and enhanced.

AKNOLEDGEMENTS

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