Internet-based tutorial providing Mathematical Complements for Technical Master Students

TIMEMathCom

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***Abstract* — The mathematical background of international students in Technical Master programs is pretty heterogeneous. They often lack of a sound basis in specific topics, which are necessary to follow the Master. Filling this gap is often stressing because it requires these students to make an additional effort reviewing basic references. The goal of this initiative is to produce a tailored learning tool for these students. Previous experiences of the proposing teams suggest that using a Moodle environment is a suitable choice to develop the tool. The idea is to cover synthetically the topics and to allow getting acquainted with the knowledge in a straight-to-the point approach.**

T.I.M.E. is a network assembling more than 50 Higher Education Institutions (mostly in Europe) with a focus in Scientific and Technical training. T.I.M.E. provides an ideal framework for developing and testing the tool. This is because the contents are enriched by the feedback of the experience of the members involved. Moreover, T.I.M.E. community is a perfect test bench for the tool.

Keywords — Mathematics; self-assessment; Technical Master Students; WIRIS; virtual learning tools.

I. INTRODUCTION

The bachelor degree in Civil Engineering (of four academic years) offered by the Universitat Politècnica de Catalunya (UPC BarcelonaTech) was designed following the European Higher Education Council guidelines and the constrains set up by Spanish regulations. This program is continuously adapted to the necessities and evolution of the students and the UPC BarcelonaTech School of Civil Engineering. Further curricular adaptations are still in progress.

In the framework of this bachelor program, the Calculus course (9 ECTS in the first year) is an example of the interest of the faculty members involved in providing a good training in basic mathematics. The teaching and learning improvement techniques used in this context are following the ideas put forward in the International Conference Online Educa Berlin [1].

More precisely, different educational tools to ease, improve and promote teaching and learning of mathematics (particularly Calculus, but not only) were developed from the inception of the bachelor program, even in the former integrated bachelor and master program, in 2003. These tools were created to motivate the first-year students and were implicitly used to update the mathematical contents of the course.

Among a number of training resources and material incorporated into this Calculus course from 2003 [2], it is worth highlighting a textbook [3]. This textbook covers the basic and fundamental issues in the Calculus syllabus, profusely illustrated, with examples, 2D and 3D plots. As complementary (and complimentary) material, the textbook offers interactive support based on Moodle and WIRIS technologies [4], [5], with online tutoring, allowing students to practice by themselves and to perform continuous assessment tests [6], [7].

The present paper focuses in presenting the MathCom project. The deliverable of this project is an internet-based tutorial tool, created with the same techniques that were tested and applied in the Calculus course mentioned above. The goal of this project is to produce a tailored distance-learning tool improving the mathematical background of the international students accepted in Technical Master programs.

The project was carried out by a consortium formed by three partners: UPC BarcelonaTech, Istituto Superior Técnico (IST, affiliated to Universidade Técnica de Lisboa) and École Nationale des Ponts et Chaussées (ENPC ParisTech). Faculty members and students were involved in the development of the material. This project was funded by the T.I.M.E. (Top Industrial Managers for Europe) International Network. The T.I.M.E. Network, founded in 1989, comprises 53 of the best schools, engineering faculties and technical universities in Europe and, more recently, in the rest of the world (Brazil, China, Japan) [8].

The remainder of the paper describes in detail the MathCom project [9], the devoted resources, and the implementation aspects. Also the impact and repercussion on the students, lecturers and the development of the course is discussed. Finally, we include some concluding remarks and future work lines.

II. MATHCOM PROJECT

A. *The project and its implementation*

As stated in the introduction, the goal of this project is to produce a tailored distance-learning tool improving the mathematical background of students in technical master programs, with special attention paid to international students. The three teams involved exhibit experience in developing this type of supporting tools for the local students (egressed from bachelor programs in the same institution) or for speakers of the local language (French, Portuguese, and Spanish).

The goal of the MathCom project is delivering a specific distance-learning tool to respond to the challenge of levering the students with some deficiency in their background, which is pretty heterogeneous. This requires complementing their knowledge in basic mathematical concepts and providing a minimum proficiency in every discipline (calculus, algebra, geometry, functional analysis…) that should allow the students to follow new concepts introduced in the course.

According to the experience of the teams involved, the best choice is using a Moodle environment [10] to develop the tool. The idea is covering the topics synthetically using a straight-to-the point approach to acquaint students with the knowledge filling their lacunas.

The project is carried out in a cooperative way by the faculty teams from UPC BarcelonaTech, IST and ENPC ParisTech. The present tool is supported, developed and tested by the T.I.M.E. community. This fact is extremely important because it allows enriching its contents by adding the experience of the participants and, more important, because T.I.M.E. community is a perfect test bench for the tool.

This online and open learning tool was launched at the beginning of the academic year 2013−2014 and it is available at [9].

The first phase of the project consisted in a review of the experience, techniques, IT platforms and contents developed in different contexts by all the members of the consortium. These existing materials were used as a starting point for the Internet-based tutorial contents. Some of the already existing contents were adapted to the new tool, requiring translation to English and some other significant modifications. For instance, the detailed explanations of the exercises were extended.

The methodology of work was based in meetings, conference calls and individual development. As a kick-off of the project, the teams from UPC BarcelonaTech and IST held a meeting in Lisbon to discuss the selection of the IT platform to be used, and the structure of the contents to be adapted or developed. The first list of topics to be included in the tool for Mathematical Complements was decided, namely: Linear Algebra, One Variable Calculus, Vector Calculus, Integral and Differential Equations, Complex Analysis, Probability and Statistics. Each topic is to be formatted with a simple and repetitive section structure: Exposition, Examples and Exercises.

A beta version of the IT platform developed under the Open Source Course Management System moodle was created following this syllabus and implemented by technical IT staff dedicated to this project. The material includes both theoretical issues, exercises and self-assessment tests. In a second phase it was decided to include two new topics in the project: Geometry and Functional Analysis.

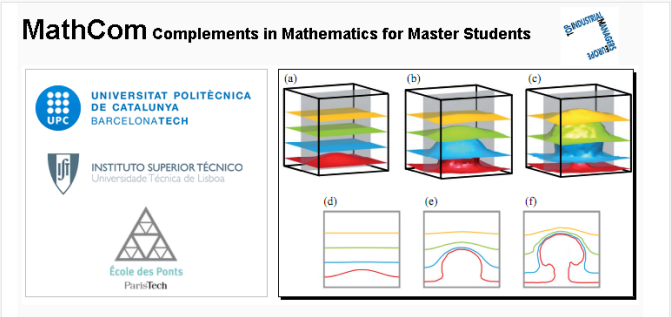

Fig 1. Topic outline

The first version of the tool included a selection of topics that were established according to the more urgent needs of the students in the master programs in which the faculty in charge is involved. The final resulting list of topics reads:

- Linear Algebra
- Geometry
- Calculus
- Ordinary Differential Equations
- Partial Differential Equations
- Functional Analysis

The complete information contained in the tool was extracted from lecture notes and textbooks [3], [11] (summing up to 180 pages in a PDF file created with LaTeX) and processed into a number of 360 Moodle pages. To ease the reading and navigation, the hypertext pages are marked with the icon . A grand total of 5.600 equations are displayed as images.

Interactive graphic material is used to improve the visualisation and understanding of specific mathematical concepts and relations. Graphic illustrations are often unveiling ideas that the students would hardly acquire by themselves. Interactive graphics are easily moved and activated with the mouse-click.

Moreover, the tool includes a hypertext Glossary allowing the user to access any particular definition by simply clicking on the words that appear with a grey background.

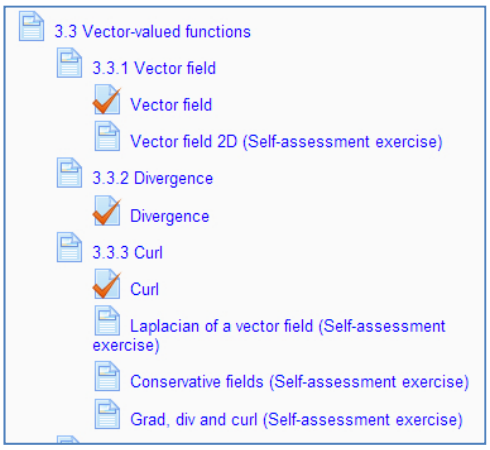

Fig.2 Calculus contents list

The students have the possibility of testing the knowledge they have acquired and their progressive learning. Currently, the tool includes around 40 self−assessment multiple choice exercises and a large number of questionnaires. All the tests and questionnaires are based on randomly selecting questions and the specific numerical input data for the problems.

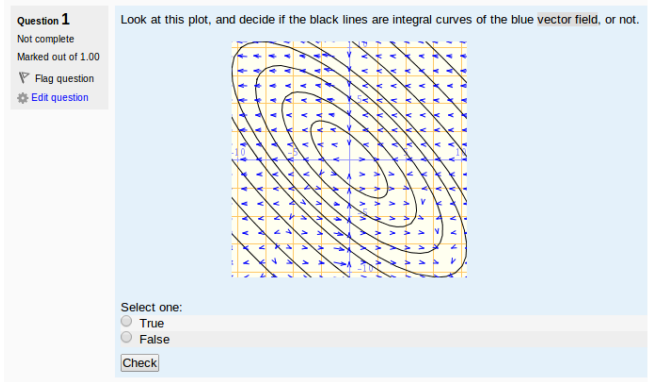

Fig.3 Question of *Vector field* Questionnaire

B. Technical innovation

The first experiences in using the tool revealed that it was important to allow the students to have feed-back on their learning progress through interactive self-assessment. In practice, an effective self-assessment system must be able to generate an enormous number of different questions. This capability of generating randomly many different questions was achieved by combining different numerical input data into a generic problem parametrically formatted. Thus, a large series of questions is easily generated and all the students are getting different questions with the same level of difficulty. This is the basic idea inspiring the development and implemention of the Wiris quizzes.

Wiris quizzes is a new system based on the Wiris CAS technology, an online Computer Algebra System which allows to compute mathematical calculations on-line as well as produce mathematical contents, that is growing up to provide Moodle questions with random values [12].

The main goal of this software is to allow the course instructors or professors to create a random family of quiz questions just by programming one through variables than can take random data. That is, every time the questions are activated, the system displays random and new data values. Moreover, these new and random values are calculated online and in real time.

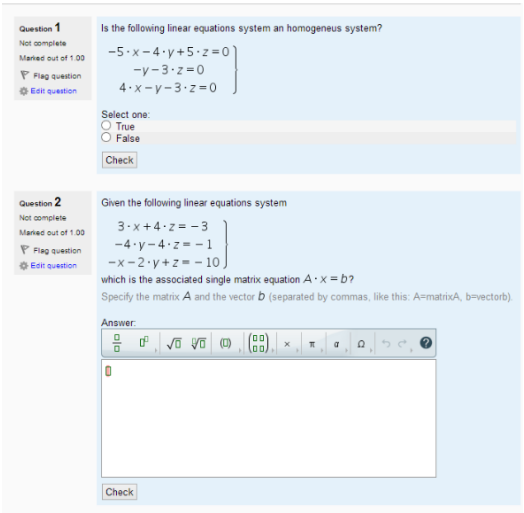

Fig.4 Question of *Linear Algebra* Questionnaire

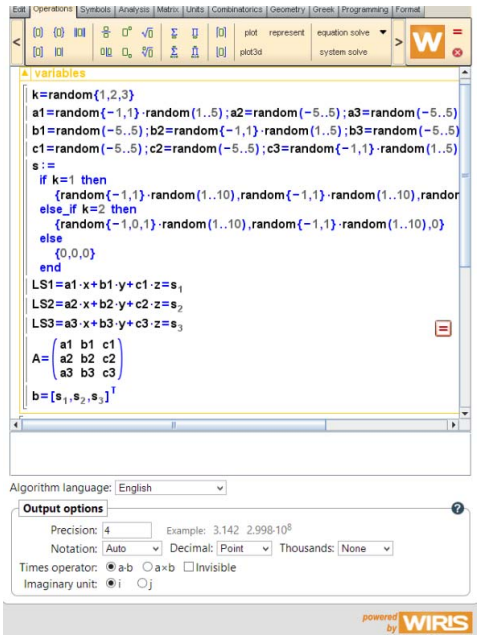

Fig.5 Math expression Wiris quizzes of the Question in Fig.4

Wiris quizzes enhance the computer-based assessment in science and in our particular case in mathematics. It is never used as an isolated application but appears inside an existing Learning Management System (LMS), like our MathCom project, integrated with the Moodle platform [13], [14], [15].

Wiris quizzes improve the question types *True/False, Multiple choice, Matching, Short answer, Essay, Embedded answers,…* The enhancements with this type of quizzes are summarized in the following list:

- Formula edition at authoring time and formula visualization at presentation time.
- Syntax validation in student answers. Real time syntax, validation if needed.
- Grading the answers considering mathematical equivalences and criteria.
- Generating random questions via an algorithm and advanced grading (when it is not sufficient to compare the student answer with the correct answer).
- Easy inclusion of 2D and 3D graphics in the questions. Such graphics can be optionally generated from random parameters.

C. *Evaluation of the content*

Continuous and generalized access to the tool through the academic web portals at any time and from anywhere is a unique opportunity to recall and acquire mathematical concepts pertaining to the bachelor programs that are necessary to follow advanced contents at the master level. A proper use of the tool is assumed to improve the study performance and the daily motivation of the Master students.

Most of the resources included in MathCom project are implemented in material developed for bachelor courses (e.g. Calculus in the Civil Engineering School of Barcelona). With this type of learning facilities, it has been observed that the students have:

- more interest in the Calculus topics studied in the course,
- a new vision of mathematics,
- more motivation to attend Calculus lectures and better learning experience during the lectures
- a complement for the lessons explanations:
  a) better understanding of what is the work to be provided while attending lectures
  b) a general idea of the concepts taught in lessons

This was the main motivation in using a Moodle environment as a suitable choice to develop the tool. Following the experience in the material developed and implemented for the bachelor courses (the aforementioned Calculus course), we prospect adding in the future audiovisual material to improve the motivational aspects and also to illustrate the theory with videos.

III. CONCLUSIONS

The inception of this project is the implementation of new bachelor and master programs at the Escola Tècnica Superior d'Enginyers de Camins Canals i Ports de Barcelona (ETSECCPB, the Civil Engineering School at Barcelona). This required a necessary review and improvement of the quality of teaching and learning activity. In particular, students are supposed now to develop specific skills and abilities, like learning independently and communicating effectively. To answer this call, the faculty in charge of the mathematical courses implemented a series of innovations and improvements.

Part of the material generated under this line of action was adapted into the MathCom tool, this is accessible in the specific website CaminsOpenCourseWare [18], which can be reached from the website of the Civil Engineering School [17]. The material like MathCom project contributes to the CaminsOpenCourseWare project improving the quality of teaching and therefore the learning process of our students. Both faculty and students welcomed these new resources. Thus, the perspectives in the use and evolution of the tool are optimistic [18].

We are convinced that the extensive use of these techniques is the way to go. The teaching and learning process is to be improved by further incorporating the use of visual and interactive materials, easily and permanently accessible and allowing both independent learning and self-assessment.

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