

ENHANCEMENT OF E-LEARNING IN GEOMATICS BY THE INTEGRATION OF DYNAMIC MATHEMATICS' TOOLS

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ABSTRACT:

The Swiss Federal Institute of Technology in Lausanne (EPFL) has introduced a Learning Management System (LMS) based on Moodle. This trend was a source of motivation for our teaching staff who have initiated a project called *Exomatic* for the enhancement of the basic course in geomatics attended by 200 students from the civil and environmental sections.

The basic concept of *Exomatic* is a collection of on-line exercises with dynamic graphical figures and smart calculus tools linked together. This platform allows a fully automated correction and evaluation process of the exercises, is appreciated by the teachers thus can save precious time.

Exomatic is mainly based on the interconnection of different resources gathered in a common web interface in order to simplify the tasks for the creation of exercise datasets and for the calculus provided by the students. This paper attempts to describe the technical structure of *Exomatic* and its performance, with a particular focus on the use of the dynamic mathematics software Geogebra. This tool is efficient for the graphical representation of geometrical features (e.g. resection, orientation).

The paper will highlight the improvement of the users' interface in the e-learning environment and underlines the importance of graphic tools for better comprehension, and the usefulness of online resources in present education. It will also present the different open source materials employed in the development of this shareable resource, which can be integrated in other geomatic courses (e.g. photogrammetry and remote sensing). *Exomatic* has demonstrated the effectiveness of online dynamics resources in teaching the basic geomatic course.

1. CONTEXT OF E-LEARNING IN GEOMATICS

1.1 Growing use of the Learning Management System

In current education learning program activity has gradually shifted from local desktop to online-based applications thanks to the popularity and the large use of Internet. Learning Management System (LMS) such as Blackboard, WebCT or Moodle have been progressively adopted to propose course content on a web interface with tools adapted to the students' and teachers' needs.

The Swiss Federal Institute of Technology in Lausanne (EPFL) introduced Moodle in 2004 at a time when nearly 4000 organisations in over 100 countries had already registered Moodle sites (Cole, 2005). EPFL's education policy has encouraged faculty members to use LMS to support and improve learning within the institution. The acceptance of Moodle was facilitated because of the easy access and usefulness for students, and the management tools with a large diversity of resources available for teachers. Its deployment has increased to reach over 650 active courses, with an average of 1500 visits per day during semester periods. (Jermann and Brechet, 2008)

Our teaching staff has naturally integrated pedagogical resources to accommodate its online course for the increasing number of students (around 200) who attend the fundamentals of Geomatics course (FG). The teaching staff has progressively used the different possibilities provided by the system. For

example, the quizzes include different response options such as multiple-choice, drag and drop, or correspondence. The quiz module offers a large possibility of questions in relation with the course content and including an automatic tallying and scoring system teacher's hints and feedback (Rice, 2006).

The social communication tools, like forum and chat, are also used for a better exchange of information within the community. These resources aim to offer a common platform to share the problems and solutions related to the different parts of the course. From the systems manager side the LMS is well adapted and its usefulness for the course is not to be demonstrated, but the present version can not propose individual learning solutions and is limited for our geomatic domain.

1.2 Lakes of LMS global solutions

A first assessment by the students (Deshogues and Gillieron, 2009) has demonstrated the specific needs of individualised calculus exercises and some graphical hints to represent geometrical features. Despite the great potential of Moodle, it was not possible to set up an appropriate solution for the specific needs of the FG course in terms of dynamic graphic representation and mathematical calculus exercises. We have decided to search for a complementary solution to associate some more learning and training resources to the central LMS. Graphical representation and automatic calculus tools in geomatics were the two domains of investigation.

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1.3 Overview of existing solutions

The survey of existing solutions was mainly composed of two parts: the commercial software for surveying applications and specific pieces of software from the open source community.

1.3.1 Commercial surveying and mapping software: Most of the professional tools provided by software companies specialized in surveying and mapping are designed to be used within the context of production. Their use in education can be envisaged in technical schools; however it is not adapted for the universities, particularly those with a large number of students. A part of the financial aspect (license fees), the use of such software requires regular activity in production which is not often the case in the educational context. Even if these types of software are user friendly for professional use, becoming familiar requires time investment for students and is certainly not adapted for the basic programme in geomatics. A further use can be envisaged in a more advanced course with a limited number of participants. In our case we decided to focus on the learning calculus software used in a large class teaching program.

1.3.2 Calculus learning software in use: Teaching the basics in surveying is closely related to mathematics and geometry. For this reason we have selected some software solutions available for algebra, geometry and mathematical computation. One existing application in this domain is Maple T.A: a web-based platform application used for creating tests, supporting complex and free-form entry of mathematical equations with intelligent evaluation of responses. This software is ideal for mathematics but requires a large fee contribution and is collocate with the Matlab software. Other solutions have been explored like WebCT, Blackboard or even LAM, Learning Activity Management System. They were able to propose a first solution without a full geomatic approach according to our needs.

Nothing was available for our geomatic course in the different existing solutions compared, it's why we decided to program a personalise application. Filling the gap with a graphic solution in the online LMS course was our first motivation in this project. Thus we have searched for compatible software to complete the online exercises program.

1.3.3 Interactive graphic representation solutions: The use of graphical representation is essential for the understanding of surveying and its related computation. Interactive Geometry Software (IGS) has been integrated to numbers of course curricula for a decade, offering open source and commercial applications to the learning community. After analysing a large list and comparing the various solutions, we have selected two interesting IGS named Cabri and GegoGebra according to our needs.

Regarding the precise comparison between both applications (Bourdy and Laroche, 2008), its distribution via a GNU¹ licence and its recognition by experts in pedagogy for its solid educational foundation, we have decided to choose GeoGebra to cheer *Exomatic* up and propose the course's graphics and illustrations to the students.

It's comparing the different solutions available in the domain and following a minimum investment policy that we decided to create a personalised application compiling geomatic needs

¹ <http://www.gnu.org/>

with calculus and graphical hints using open source solutions for its generalisation.

2. CONCEPT AND IMPLEMENTATION OF EXOMATIC

2.1 Structure and presentation of the course

The fundamentals of geomatics at EPFL are given in the first year of the bachelor degree. The content of the course is mainly composed of the basics of geodesy, and surveying techniques for the acquisition and representation of geographical data. The teaching method is based on one period of lecture and another period of exercise (survey calculus). This course is offered to the both environmental and civil engineering sections. Since the total number of participants has increased, the teaching staff has to search for new pedagogical solutions for maintaining the same quality of support to the students. This was the main motivation for introducing Internet based teaching (e-teaching) and online exercises. Figure 1 below presents the structure of the course: separated to two sections, the course balances traditional face-to-face and online teaching methods. The interoperability between them ensures a common way of learning how to exploit the various resources as fully as possible.

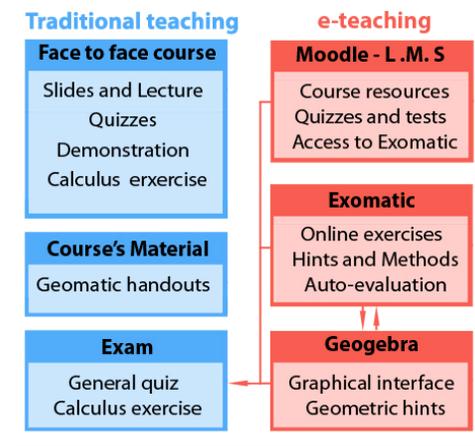


Figure 1: Structure of the FG course

2.1.1 Traditional teaching remains: The main concepts and algorithms are explained and demonstrated during the face-to-face lecture. During such a time period students are mostly not very active and the assimilation of knowledge is not very strong. However, more effective learning can be obtained thank to the exercises where students must be active doing it by themselves.

We wanted to optimise the effort made for the lecture and we encouraged students to complete the weekly and common ex-cathedra contact hours with online resources for their time studies. By moving some parts of the course on the LMS, we did more effectively take advantage of scheduled face-to-face time to engage students' questions and ideas (Cole, 2005)

Pedagogically we passed from a traditional method of teaching to an e-teaching personalising the way of learning for the students.

2.1.2 A course toward e-Teaching: The introduction of e-teaching methods will not fully replace the traditional approach, but will be a way of improvement integrating new technologies as a support for both instructors and learners. Therefore the architecture of the e-learning system is a key component for the success of its development. As stated by Dalsgaard, the choice of a variety of tools will better support the required flexibility of open-ended activities than any one integrated system (Dalsgaard, 2005). This is why instead of integrating all the functions within a unique system, our approach suggests making available several tools with independent functionalities. The e-teaching course part is aimed at providing adaptable toolboxes to the students regarding their progress and results. In our case, web-based technologies are used like a set of different tools and resources accessed via the central management system in order to reduce the interfaces for data exchange. Students' self-governed and calculus-solving activities are the principal point of a learning process for the FG course; this is why an individual exercise data program has been developed to support a self-governed and constructive process of learning. *Exomatic* as autocorrected online exercises ensures a student's independent work process.

2.2 Exomatic as a new pedagogical resource

Exomatic is mainly a set of online exercises developed in accordance with the students' and teachers' specific needs for the FG course. As mentioned above, we wanted to move the e-teaching course beyond the central LMS and encourage students in an active use of this specific resource for their self-governed learning. (Masterman and Goodman, 1997) further contend that using computers and calculator-based interfaces in the science classroom will also promote "self discovery" (Kreuger, 1998).

2.2.1 Concept and implementation: *Exomatic* is the autocorrected online collection of the traditional paper exercises in order to provide students individually with direct hints and theoretical summary. Its implementation in the curriculum gives the opportunity to continue and practise the exercise presented during the contact hours. This possibility engages students in an active way of training and learning. This resource can be used as a refresher activity to practise and improve the student's skills, and to bring them a personal update in preparation for the exam. *Exomatic* is also an administrative tool for the teaching staff to facilitate the conception of exercise's datasets and access to students' statistics and program activity. To propose this different opportunity, *Exomatic* integrates different web technologies.

2.2.2 Technical definition and software components: The user part looks like a standard web page. Behind this simple interface, the program is running a couple of specific processes interacting with the database, the graphical tools and other web technologies. Technically, *Exomatic* is an Internet application combining basic HTML pages bolstered by scripting languages communicating on the server side with user actions, the algorithm and the database. PHP and Javascript dynamic script languages are associated with some Application Programming Interfaces (API) in order to facilitate the conception of exercise datasets and interactive calculus toolboxes. PHP or Hypertext Pre-processor is used in our case to bring some interactivity to the web pages and ensures the link between the different components. Figure 2 summarizes the technical components used by the *Exomatic* project.



Figure 2: Software components

As shown in the previous figure, most of the components are standard products combined in the Wamp² package. This choice makes *Exomatic* an evolutionary programme which can be adapted to future needs and to the next versions of the basic software components. The *Exomatic* web pages are hosted by the institute's server to enable the process of several requests and promptly react to the different users' queries. The different variables associated to the different exercises can be declared and created in several ways, such as dynamic JavaScript user action, Structured Query Language (SQL) under the source code regarding conditional expressions, hidden information from the LMS, declared by the students in their exercise progression, or directly extracted from the database.

The database provides a multi-user access and ensures the information storage of student and exercise variables. We have chosen the MySQL Database Management System (DBMS) solution to store the collection of data linked to the exercises (solutions included). We are also using the visual interface name phpMyAdmin, to create and facilitate database management.

Administratively, *Exomatic* needs the presence of a webmaster to develop and ensure the continuity of the project from the initial conception to the provision of a new exercise in the collection. This step has to be done manually under the source code of the different files using special programming software to write the script and gather the different components. But before explaining the details of their interconnection and the utility of the IGS in our case, it's important to define the semantic organisation and the information flow browsing the program.

2.2.3 Semantic organisation and information flow: As described above, *Exomatic* is a cross-platform application that automates the production and marking of individualised exercises. It is a collection of interactive procedures which are connected simultaneously to a user interface and to a database. Summarized in Figure 3, the following section describes its global concept and its semantic view. This figure shows the interaction between the actors (teacher, students) and the technology (web server, database).

1. The teaching staff creates dynamically the exercise datasets with an automatic generation of the results used in the correction phase (7).
2. Once connected via the LMS with user-name and password to the *Exomatic* webpage, 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, as the program automatically saves this information on a student profile database.

² <http://www.wampserver.com/>

3. The data from the exercises are randomly generated to provide specific numerical values to each student. All sets of data are transmitted directly to the user interface and displayed with the possibility to check at the end of the exercise, the validity and the correctness of the answers.
4. Once his calculus done, the student answers via an HTML form.
5. These responses are integrated into the student's database via the server.
6. In case of bad numerical values or wrong answers, the program issues a warning and proposes to restart the exercises, displaying the student's initial values on the different forms.
7. The automated correction of the exercise 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. The results and the feedback are automatically presented to the student. In case of inaccuracy or bad results, a simple click on an icon allows the user to access hints and advice for a better comprehension of the error committed.

8. Statistics such as connection number, student success per question or exercise are available to the teachers.

(Deshogues et al., 2010)

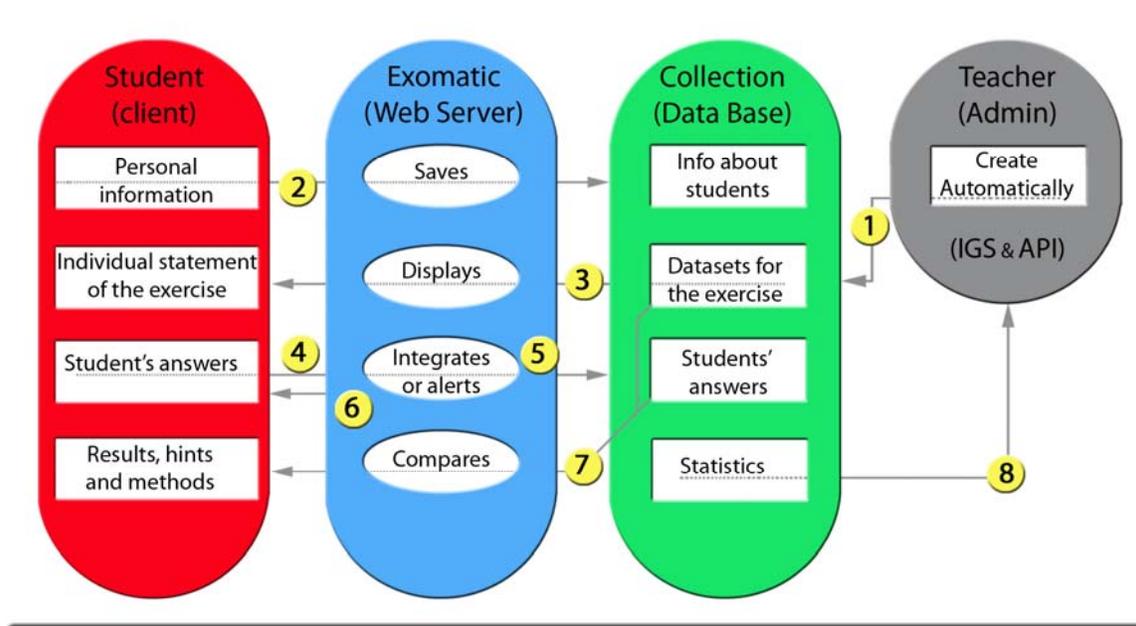


Figure 3 : Semantic organisation and information flow

The previous figure demonstrates the global semantic organisation of the program. Figure 4 below illustrates the different steps of a typical online exercise. *Exomatic* activities describe a learning process in which students are directed at solving surveying problems. Divided into four separated stages, the online exercises have been constructed to facilitate students' comprehension and progression. Different steps have to be followed by the learners to solve the entire exercise. The first step is dedicated to introducing the exercise and its context followed by the first questions. Most of the time the values obtained from the initial questions are needed to solve the next step. The second stage has been created considering this problem and proposes a first validation step in student progression.

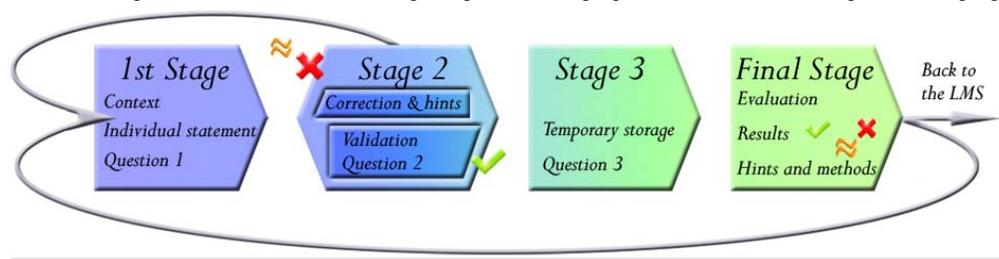


Figure 4 : Exercise's steps followed by the learners

If the student answers the first group of questions correctly, the program distributes the different steps until the final one displaying student's results and evaluation with some more hints and methods to better appreciate their mistakes. Along these different stages of progression, graphical hints have been integrated to guide the learner in his study approach. The following sections present the interactive geometry software and its use cases in the course and in the *Exomatic* program.

3. ADVANCED GRAPHIC INTERFACE

As discussed previously we have decided to use GeoGebra for the graphical representation of the surveying concepts. Figure 5 presents a typical example: azimuth traversing.

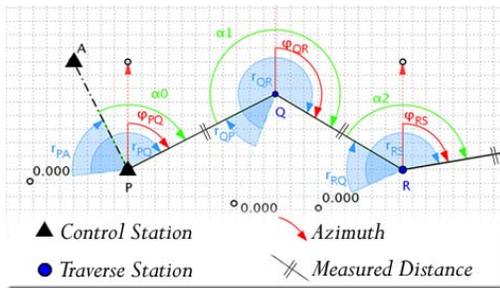


Figure 5 : GeoGebra's scheme

As an IGS, it enables the production and the manipulation of geometric constructions. In addition GeoGebra is compatible with the European standardisation project INTERGEO³ which aims to organise and improve the interoperability of geometry software in the European education.

3.1 What is Geogebra?

GeoGebra is free software that joins geometry, algebra and calculus for mathematics and geometry education. Open source under General Public License (GNU, free of charge) and available in more than 45 languages, it proposes the construction of geometrical objects such as points, lines, or angles and more specifically all conic sections, vectors, parametric curves and locus lines. All these options were quite sufficient for the specific needs of our exercises, where angles and distances are most of the time enough to construct our graphics.

GeoGebra allows a direct input of cartesian or polar coordinates, linear and quadratic equations; calculations with numbers, points and vectors and other algebraic possibilities.

For the algorithmic calculus one can directly input some functions; intersections; symbolic derivatives and integrals built in Computer Algebra System (CAS); and sliders as parameters. One of the significant advantages is that GeoGebra's graphics are exportable as web pages using a JavaScript interface especially useful for our online exercises configuration. (See following section 4)

An interesting option for our pedagogical purpose is the animation tool that permits the decomposition of the construction, and presents, step by step, the process involved in the graphic construction. These animated graphs are very useful during the lecture in order to illustrate algorithms and also as online resources associated with the hints proposed to the students. GeoGebra is available on diverse commonly used software platforms such as Windows, Mac OS, Unix/Linux, and all the systems supporting Java language, but nothing is already available for the smart-phone environment.

GeoGebra presents two types of configuration: a desktop version and a web applet using Java⁴. The desktop application is designed for the construction of graphics and different geometric features. The Javascript applet is used to display the graphics on the web pages and also to communicate with the server side.

³ <http://i2geo.net/>

⁴ <http://www.java.com/>

3.2 Graphical and comprehensive interests for students

In most IGS, the user can start the construction by setting a few points and using them to define new objects such as lines, circles or other features. Comparable as a heuristic method of teaching allowing students to learn by doing from their own experiences, GeoGebra must be profitable for their comprehension and progress. For example, the students can move the points on the original figure or scheme and they can see how the construction is modified.

To validate this hypothesis within the context of *Exomatic*, an assessment by the users will be held by the end of the semester.

3.3 Pedagogical added value for teachers

The desktop software is used to construct the different figures used for the lecture and the exercise. Animated stepwise construction, dynamic calculus toolboxes, algorithms representation and generation of datasets are just a few examples of the various options offered by GeoGebra.

The main advantage for the teaching staff is the interactivity of graphics which is an easy way to create use cases in surveying. This possibility exists also with commercial software (e.g. Autocad). However this integrated solution is adapted to teaching needs, e.g. the creation of a large amount of individualised datasets, for more than 190 students. Using the same tools for the ex-cathedra lecture and for the exercise is also fruitful: it improves the link between the course content and the practical use of algorithms for calculus.

4. INTERCONNECTION OF DYNAMIC TOOLS

As mentioned above the process starts with the construction on a desktop platform of a graphic composed of basic elements. After this first step, the GeoGebra applet is called by an HTML page. Figure 6 presents the different use cases of GeoGebra and their interconnections with the user interface, the script languages and the database. The links (4.1 – 4.4) between the different components of the software are technically developed in the next sub-sections.

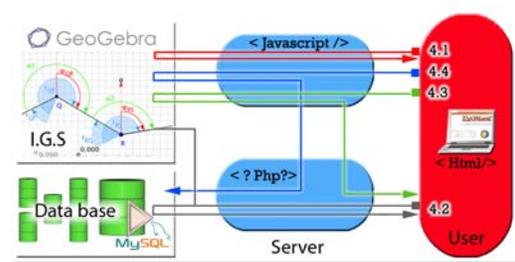


Figure 6 : GeoGebra in different ways.

4.1 Basics API's Javascript functions

Directly displaying the graphic view on the webpages of *Exomatic* via the API is one of the commonest and largest uses of GeoGebra. The user is able to interact with the geometrical variables set on the scheme using the various JavaScript functions directly embedded on the API or with action buttons. Based on this principle, mathematical algorithms or representation regarding use cases can be decomposed and dynamically readjusted regarding the users actions on the graphic's parameters.

4.2 Setting GeoGebra's parameters with exercise data

GeoGebra offers other modes of use than the classical applet. These possibilities allow the interconnection with a database using PHP functions, which improves the software solution of *Exomatic*. Starting from an original figure of the context, the user can adjust and reconstruct the scheme with his individual dataset provided by the database. By an action button, a Javascript function uses the student's parameters (from the database) to re-adjust the graphic. In this case, this visual method presents results graphically, which offers the possibility to the students of correcting their own results.

4.3 GeoGebra's variables under calculus algorithm

This is the typical use of calculus toolboxes with specific functions linked to the exercise (e.g. azimuth, trigonometric functions). In this case there is no need to obtain a communication between the user interface and the database. Such as a calculator input variables are independent and the output data don't really need to be stored. Calculus toolboxes are available in the final stage of the exercise with two possibilities of use. The first one consists of filling in a form with input values from the exercises and running the calculus algorithm. The program will return the expected answers with some explanations of the detailed process. The second one uses a GeoGebra applet to get dynamically the different input variables. Firstly, all the user's actions on the graphic view modify the variables. Secondly, a query is used to collect the new graphic variables and to store them on the appropriate cells of the form. The next action consists of running the PHP programme (calculus algorithm) with the new variables. Finally, the server returns the expected answers with all calculus details.

4.4 Processing Javascripts' variables and database content via PHP's functionalities:

The final important function is dedicated to the teacher's needs and is the most complex and fruitful use of the IGS in our programme. The objective of this part is to optimise the use of the graphic by exploiting the dynamic generation of exercise datasets developed for *Exomatic*. On one hand the user's actions via the applet modify the graphical variables and the action buttons interact with the graphic via Javascript functions. The variables corresponding to the input datasets are automatically stored and displayed on an HTML form. On the other hand, some other variables related to the calculus (e.g. units, expected precision and physical parameters) have to be chosen and validated via a simple html option menu. Once all the variables are defined, they are processed by the PHP code. As a first step, the variables are directly written in a table of the database. They will be reused by *Exomatic* to display a new set of exercises to the students. The second step consists of processing the input data. Integrated on a PHP script, they are processed by several calculus algorithms in order to obtain the expected solutions to the exercises. Finally, the processed variables are stored in the database as a new dataset available for future exercises. At the same time a unique identifying number is stored into the database for linking the input data and the calculated variables. This parameter is important for the exercise's correction and the student's evaluation. User information is also linked to the table ensuring a good traceability of the dataset.

Getting the state of objects is available via JavaScript's functions but their combination with PHP allows us to optimise the use of the IGS communicating with the server side, processing the variables and storing them in the database.

5. CONCLUSION AND FUTURE WORK

5.1 Conclusion

Using the GeoGebra application was an exciting experience for surveying education. It is a valuable component of the web based *Exomatic* program and the course in general. This application has shown a great potential with different methods of use, especially with its collocation with PHP, JavaScript and a database. The choice of such a graphic tool is a clear advantage for the geomatics domain which requires a high level of interactivity. At this stage the students' autonomy is increasing and the e-teaching resources come in addition to the lecture notes and face-to-face lectures. All the resources are already considered useful by the students and *Exomatic* is an added value to the course content. Its development was performed by a small team working close to the students' and teacher's needs: the best configuration for providing an fitted solution for the production and the realisation of online exercises. The co-operation of students allows the teaching staff to design further improvements!

5.2 Future work

A detailed assessment by the users will be held at the end of the semester. After that we will focus on the development of learning scenarios based on *Exomatic* and other resources towards a better integration of the course content and on-line resources. One of the final goals is to share this type of resource with the geomatics education community. As *Exomatic* is based on open source software, it is easy to give access to the code to other teams and, why not develop common resources between different institutions. At the same time we would like to improve the use of graphical tools for teaching and creating a new Geomatic community under the wiki web pages of GeoGebra to share the different exercises elaborated for the FG course and to participate in the enrichment of an online exercises' collection.

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