

# DEVELOPMENT OF AUTONOMOUS LEARNING TOOLS TO ENHANCE STUDENTS LEARNING IN SCIENCE AND ENGINEERING

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## Abstract

In recent years computer science courses have become more and more common in science and engineering degrees. However, lecturers face a complex task when teaching this subject: students consider the subject to be unrelated to their core interests and often feel uncomfortable when facing computational concepts for the first time. A non-traditional approach might help students to overcome their difficulties. Several studies have proposed the use of autonomous learning methodologies to improve student involvement. Students in control of their learning processes tend to attain higher learning levels, higher confidence and greater satisfaction.

This paper presents an autonomous learning research project conducted at the Faculty of Sciences at the University of Granada. The aim of this project was to develop new computer-based tools that will support the autonomous learning of computer science topics by Chemistry Engineering and Biology students: a set of interactive animations, which will enhance the student's learning process; a series of screencasts that explain the subject main topics, and a computer system capable of generating different exercises for each student in an automatic way. A database of questions related to computer science has been developed together with several tools to create automatic quizzes. All the materials developed have been placed on an online server that the students can access wherever and whenever they want. In order to evaluate these learning-supported tools, we have compared their results with those obtained when these modules were not available. We have found that there is a significant group of students that have improved their learning thanks to the additional material. Students have also expressed their satisfaction when using the autonomous learning tools.

Keywords: Autonomous learning, interactive animations, screencasts, postcasts self-evaluation.

## 1 INTRODUCTION

The adaptation to the European Higher Education Area (EHEA), currently being developed at Universities of more than forty European countries, has meant a transformation not only in the organization of higher degrees, but also in the traditional way of teaching [1]. The adaptation to the EHEA supposes new roles for the teaching staff and students shifting to a higher education system based on the autonomous learning of specific and generic competences. The adoption of these new roles implies moving towards a student-centred teaching using different methods and teaching media - online and offline - that can promote active constructive learning.

The EHEA adaptation of the new curriculums at the University of Granada, Spain, has given rise to a set of new courses with themes designed specifically for freshmen. An example is the computer science course "Fundamentals of Computing" implanted in the Biology and Chemical Engineering degrees. Thought, since 2010 these courses have become more common in science and engineering degrees due to the fact that engineers and scientists are increasingly relying on computers for their work, the lecturers face a complex task when teaching this subject. Students of Computer Science and Engineering often find difficult to learn the main concepts associated with programming and the use of algorithmic reasoning [2]. Moreover, in many cases, they have a very negative perception of computing as a subject very remote from their field of interest and that implies the capacity of conceptualization and abstraction at different levels. This perception of the subject makes even more difficult the learning since the emotional component ballast the learning process.

In this scenario, we think that the use of new innovative teaching methodologies centred in the autonomous learning and student self-assessment can be an alternative [3]. The use of multimedia resources can provide an attractive and motivating environment for students to promote their learning by improving the students' implication [4]. Moreover several studies have proposed that students in control of their learning processes tend to attain higher learning levels, higher confidence and greater satisfaction [5].

Following this line of thinking, this paper presents an autonomous learning project conducted at the Faculty of Sciences at the University of Granada. The aim of this project was to develop new computer tools that will support the autonomous learning of computer science topics on-line by Chemistry Engineering and Biology students. Students from the Chemical Engineering and Biology degrees at the University of Granada have used these modules during their computer science courses.

The project has been evaluated by assessing the performance of students following these methods and comparing their results with those obtained by students in the same courses when these modules were not available. The results show that there is a significant group of students that have improved their learning thanks to the additional material. Additionally, we also see an increase in students' satisfaction when using the autonomous learning tools.

The obtained results show that these new tools represent a significant improvement in the learning process for over five hundred students of Chemistry and Life Sciences. It is our belief that these modules can be easily applied to other computer science courses in engineering and science degrees.

Therefore, in order to describe the learning project, our paper is divided in the following parts: Section 2 presents the description of the tools that we have incorporated, as well as the evaluation methodology that we have followed to test the application of the project. The results and some discussions about them are found on Section 3. Finally, Section 4 will present some conclusions.

## **2 MATERIALS AND METHODS**

### **2.1 MATERIAL**

On the one hand, we present the context in which this experience is framed: the autonomous learning project has been applied to students coursing the computer science subject "Fundamentals of Computing" implanted in the Biology and Chemical Engineering degrees, referenced by FIIQ and IAB, in their Spanish acronyms. In both grades these courses have been assigned a broad set of skills and competences and cover a wide range and variety of topics describing the applications of computer to science and engineering. The "Brief Description of Contents" of these courses includes: office automation, programming, operating systems, databases and software use with applications in engineering. In the case of the Biology degree also includes a specific mention to Bioinformatics. To address these contents the curricula is divided into three modules: introduction to computer/office automation, database fundamentals, and introduction to programming in Matlab.

On the other hand, we have to mention that the use of the Information Technologies and Communications (ITC) is the cornerstone of our project, being particularly useful for the adaptation process to the new European Higher Education Area (EHEA) and very efficient promoting autonomous learning and the interaction between both agents in the teaching-learning process. Within this ICT environment, the virtual Modular Object-Oriented Dynamic Learning Environment (Moodle) platform arises as an option for the promotion of these activities [6]. The project here presented focussed in the design and evaluation of the effect in the learning of student of interactive presentations, self-assessment questions, and screencasts, all of them implemented in the Moodle platform <http://bombon.ugr.es> at the UGR.

In the following sections, we are going to presents the different methodologies that support this learning project.

#### **2.1.1 Interactive presentations**

Interactive presentations are strategies that allow students to review and reinforce the content provided in class, while allowing them their own organization and evaluation of the learning. The interactive slides here presented, are created using PowerPoint and later made interactive through the tool Adobe Presenter. The access to these presentations can take place through an Internet browser enabled to play Flash files. Visualization takes place as in a traditional HTML websites, with the

additional possibility to interact with the elements implemented in the presentation. Once the students are finished with the interactive presentation the system asks questions to ensure that they have assimilated the contents and knowledge exposed in each block of interactive presentations (See left hand side image in Figure 1).

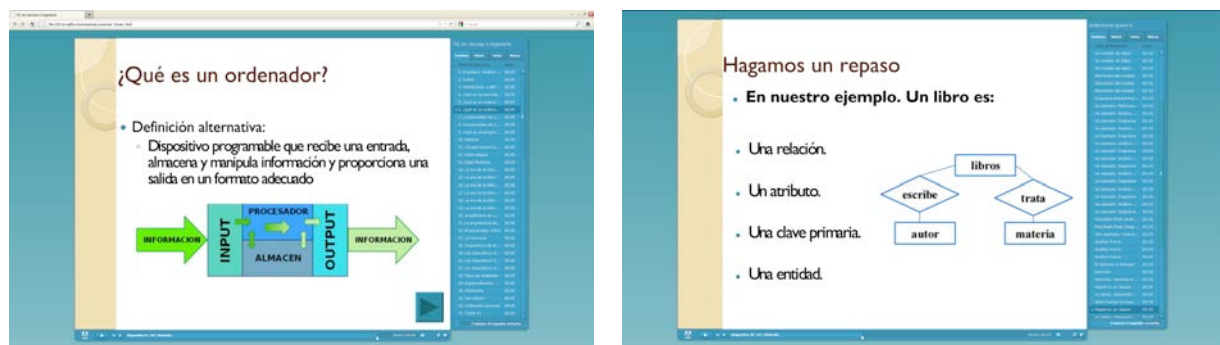


Figure 1: Example of an interactive presentation and an interactive question.

In order to move forward and access other contents, the student must correctly answer the previous questions. This control allows on one side to focus students' attention on a particular task, as new contents will not be provided until the previously one have been assimilated and positively evaluated. On the other side it provides the student with a feedback of their learning process (see right hand side image from Figure 1).

### 2.1.2 Self-assessment questions

Self-assessment questions have been proved to be powerful tools to reinforce students learning [7]. The “self-assessment” tool consists of a database of questions and several tools to create automatic quizzes. These elements have been implemented using open source platforms to facilitate and ensure its maintenance over long periods of time. This tool is simple to use and indicates if the training has been effective or not, allowing as well the automation of the correction process by providing the right answer to each question. The lecturers are responsible for the expansion of the database by adding new questions and improving the capacity for self-assessment of the tool. Each question will be associated with a content block of the subject's curricula in our case: office automation, database design or a programming language (e.g. Matlab).

Once the student accesses the system, this will automatically produce the auto-evaluation test in an individual manner, but always following the guidelines set by the teacher. Once the self-assessment questions have been answered by the student, he will be able to see his answer to each question and the right one being able to repeat the test as many times as he desires in order to evaluates his learning process.

### 2.1.3 Screencasts

We have designed and recorded five video screencasts that review carefully the contents more difficult to understand by the students and those for which they need more time during the practical sessions of the course. The basic purpose of this material is that students can spend time at home reinforcing these concepts and methodologies in order to get a better use of the practical classes [8]. This autonomous work at home allows the teacher to focus on more complex aspects during the class. These videos are between 5 -20 minutes in which a concept, a procedure or a comparison is exposed following an introduction, a description of the problem and the development of the topic.

### 2.1.4 Modules description

We have also developed learning modules convinced that new technologies are a useful tool in the learning process of the students, which make the process much more attractive allowing the access to the information from any place connected to internet. To address the curricula of “Fundamentals of Informatics” in Science and Engineering degrees, its content was divided into three modules with a similar structure and consisting of an on-line organized sequence of information, which can include interactive presentations, self-assessment tests, and screencasts. The modules include instructions for the student about the use of the module, and relevant information such as the dates of availability, or deadline of availability. Completing each module implies a dedication of 1 to 2 hours of autonomous

work of the student. There are a lot of materials available in the web but besides one video about the History of Internet, all material developed by the staff involved in this project is original. The work team has designed, created and developed original material such as images, presentations, tests, videos. All material is available at the Moodle server. The three available modules are organized as follows:

- 1) Introduction to computer/office automation module: Contains a video about the Internet History, three Office automation interactive presentations: Introduction to excel; Formulas in the Excel package; Use and creation of Graphics with Excel and a self-assessment quiz about the module.
1. Database fundamentals modules: contains two interactive presentations: Introduction to Databases; Theoretical and practical exercises with Databases and a self-assessment quiz about the module.
2. Introduction to programming in Matlab module: contains two interactive presentations: Introduction to Matlab; Programming with the Matlab package, as well as, a self-assessment quiz. Additionally, there are five available screencasts:
  - a) First contact with the Matlab programming environment (15'). The contents include: the Description of Matlab and windows (5'); Matlab interactive and use of some expressions in the command window (4'); Help support in Matlab (3'); File opening and running of sample code in the command window (3').
  - b) My first script with Matlab. The contents include basic handling of files, such as opening and saving; Creation of new files and their execution.
  - c) My first function in Matlab (10'). The contents include: Creation and definition of a simple function; Definition of functions with argument; Execution of a function from the menu and command line; Embedding a function call in another script.
  - d) Common programming mistakes and debugging tips for Matlab (20'). Objectives: To teach students how to track and correct common mistakes when programming with Matlab. The contents include: Tips to navigate through the file system and to configure correctly the working directory; Example of use of a nonexistent function. Using the help to find the correct name of a function. Example of common syntax errors and error messages in Matlab. Debugging code. Stepping to identify anomalous behaviours. Using breakpoints in the code to stop execution. Monitoring variables and debugging techniques.
  - e) Installing Octave, an open source platform similar to Matlab (5'). The contents include: Download and install (step by step) of Octave on Windows computers.
  - f) General comparison between Matlab-Octave (5'). The contents include: Comparison of the command Window between Matlab and Octave; Management support in Matlab and in Octave; Running a script from Matlab and from Octave; Creation of a function in Matlab and Octave
  - g) Programming exercise in Matlab.

## 2.2 METHODOLOGY

To examine the effect of all the developed material in the students' learning process, we selected the students from the Chemical Engineering and Biology degrees at the University of Granada. These students have used the described modules during their computer science courses as additional material that could be used at home or at the computer labs habilitated in the Faculty for the students.

At the beginning of the course the Moodle server was presented, and we habilitated the enrolment system for the students. During the semester, we sent several notifications coinciding always with the beginning of a content module. These emails, included information about the location of the server and the content made available. Several teachers made use of the Matlab screencasts for explanation in the classroom, which also served as a guided example on how to access to the material in the server.

For the evaluation of the results after the implementation of the methodologies mentioned we have used three different approaches:

- Surveys: During the last two consecutive years we have distributed satisfaction student surveys. The questionnaire consists of 11 questions, 10 of which follow the Likert scale of 4 points and one free response question for suggestions. The questions can be divided into 3 groups: 1) six

questions about the content of the subject. One general question about the course, four questions concerning each of the parts of the course, and a question about the practices. 2) Three questions on the evaluation of the subject that match the three individual tests performed by the students during the course. 3) Questions about the teaching performance of teachers in theory and practice. The sample consists of a total of 61 students from the Biology Degree (42.62.4%) and Chemistry Engineering Degree (55.74%) at the University of Granada. These students completed the subject “Fundamentals of Computing” involved in the teaching innovation project developed during the 2012-2013 academic year.

- Server usage patterns: the frequency of the students’ access to the server, as well as the semester time when they logged in the server was analyzed.
- Comparison of student’s results with and without the use of these methodologies: We proceeded to compare the results of the students of the Chemical Engineering and Biology Degrees this years with the performance of the previous two years were the methodology was not available but the theoretical and practical contents were identical.

### 3 RESULTS

#### 3.1 Surveys

The survey was split into several groups or units that included Multiple Choice (Only One Answer) questions concerning the usefulness of different tools of the platform. In these cases the students were asked to report one answer on a four-category scale (“Much”, “Normal”, “Little”, and “Nothing”). Finally, there is one open ended – multiple lines question. The survey is the following one:

**1. General questions:**

- 1.1 How much interesting are the materials published on the platform?
- 1.2 How much help you the materials published on the platform to improve your learning of the subject?

**2. About Interactive Presentations:**

- 2.1 How much like you these presentations?
- 2.2 How much help you these presentations to improve your learning of the subject?

**3. About Screencasts:**

- 3.1 How much interesting are these screencasts for you?
- 3.2 How much help you these screencasts to improve your learning of the subject?

**4. About Self-Assessment Tests:**

- 4.1 How much appropriate are these tests for you?
- 4.2 How much help you these tests to improve your learning of the subject?

**5. About Personalized Homework:**

- 5.1 How much appropriate are these personalized homework for you?
- 5.2 How much help you this personalized homework to improve your learning of the subject?

**6. General evaluation:**

- 6.1 Could you give some suggestions, contributions, and comments about using the materials of the platform?

Initially, the general findings regarding the platform uses are reported. Next, the specific results related to each kind of material published are presented.

Regarding the general opinion about materials published on the platform, the majority of the students in the sample (see Figure 2) stated positively (46% “much”+ 43% “normal”) that the materials are interesting. Only 3% reported “little” and 5% reported “nothing”. Figure 3 shows the answers to the question 1.2, where 52% of students reported that the materials “normally” help to the subject and 30% reported that they help “much”. In the other side, 10% reported that these materials contribute “little” and 5% that did not help anything. 3% of students did not answer the question.

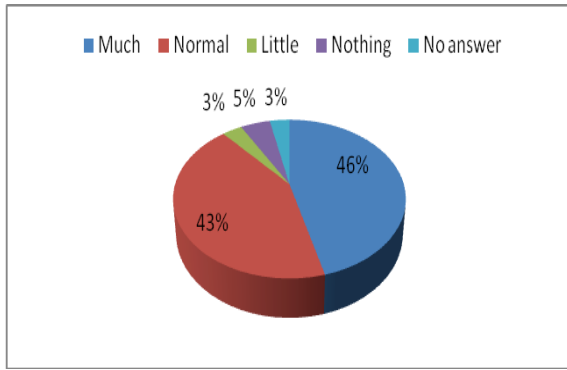


Figure 2: Answers to question 1.1.

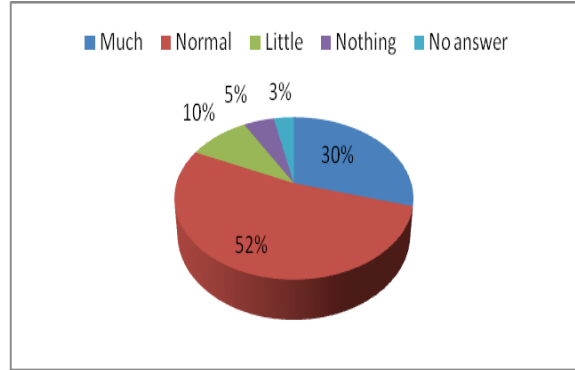


Figure 3: Answers to question 1.2.

With respect to the Interactive Presentations, they “normally” liked to 48% of students and liked “much” to 29% of students, as seen in the Figure 4. This last number is almost the same percentage of students who said “little”, plus those who said “nothing” (15% + 5%). Figure 5 displays that slightly more than half of students (54%) said that these presentations are useful in a “normal” way to improve their learning of the subject and 26% reported “much”, whereas 15% and 5% reported “little” and “nothing”. 3% did not answer this question. We can conclude that interactive presentations liked to majority of students and they are useful as materials for study and independent work.

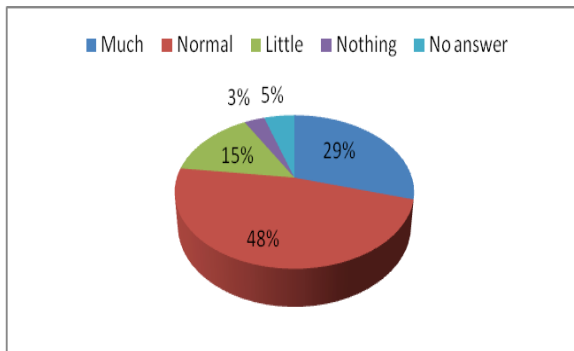


Figure 4: Answers to question 2.1.

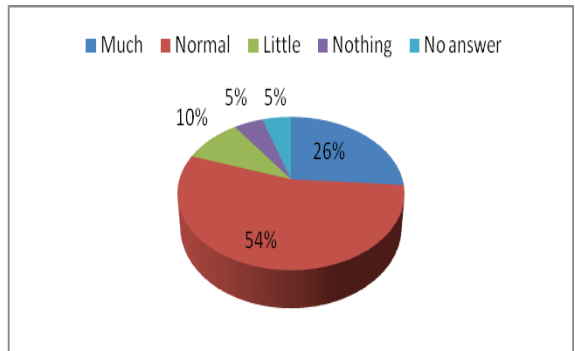


Figure 5: Answers to question 2.2.

About Video Screencasts, they were considered “little” and “normally” interesting for the same percentage (28%) of students (see Figure 6), while only 20% said “much”, 8% said “nothing” and a high percentage (16%) did not answer this question. About the question 3.2 of how much these screencasts help to student to learn and study the subject (see Figure 7), a 35% reported “normal”, a 21% reported “little”, only reported 16% “much” and a high 12% reported “nothing”. Same as above, 16% did not answer this question. These results show that published videos should be improved and the content displayed to be reconsidered.

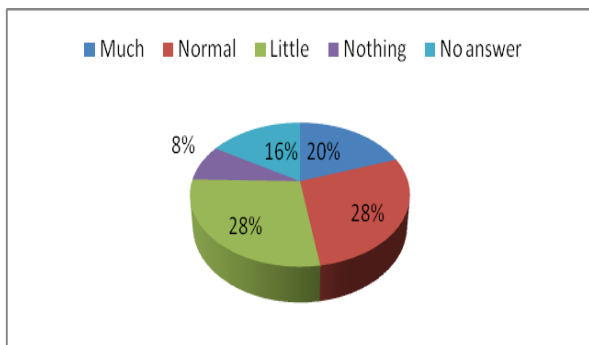


Figure 6: Answers to question 3.1.

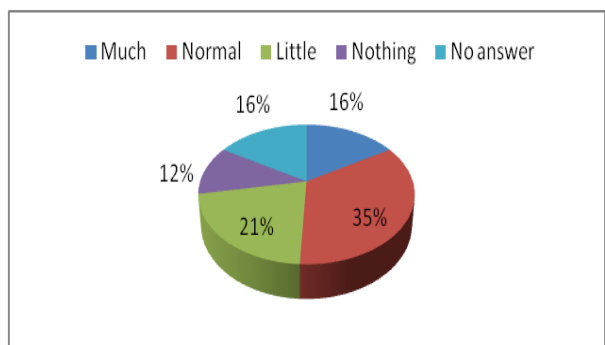


Figure 7: Answers to question 3.2.

Considering the answers to the Self-Assessment Tests questions, we have to mention that 38% of the students considered “normally” appropriate these tests, 24% said “much” and 20% said “little” (see Figure 8). Again, a high 13% did not answer to this question, and 5% stated “nothing”.

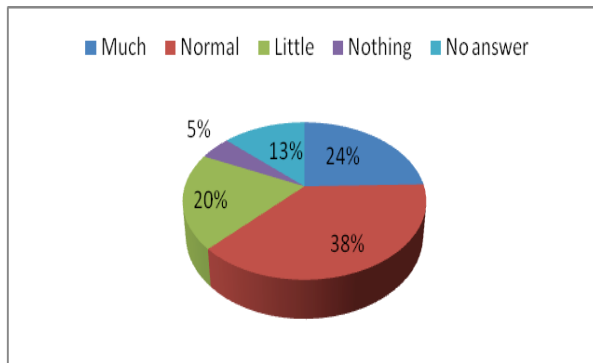


Figure 8: Answers to question 4.1.

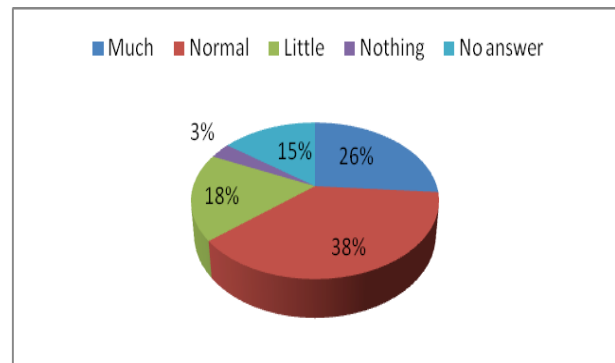


Figure 9: Answers to question 4.2.

Similar results were obtained (see Figure 9) in answers to question 4.2 about how much these tests help the students to learn and study the subject: 38% stated “normal”, 26% “much”, 18% “little”, 3% “nothing” and 15% did not answer to the question. We can conclude that these tests were normally accepted by students.

Finally the analysis of the questions related to Personalized Homework: about half of students (48%) said that these personalized homework are “much” appropriate to improve the study of the subject (see Figure 10). A very high 84% of positive answers are obtained if the 36% of student that stated “normal” is added to the last result. In the other side, 11% of students stated “little”; only 5% stated “nothing” and 3% did not answer this question.

Similar results were obtained (see Figure 11) in positive answers to question 4.2 about how much these homework help the students to learn the subject: 38% stated “much” and 48% “normal”, 13% of students stated “little”, only 3% stated “nothing” and 3% did not answer to the question. It is very interesting that extensive and difficult homework have been well received by students, and even more considering that every student work on their own.

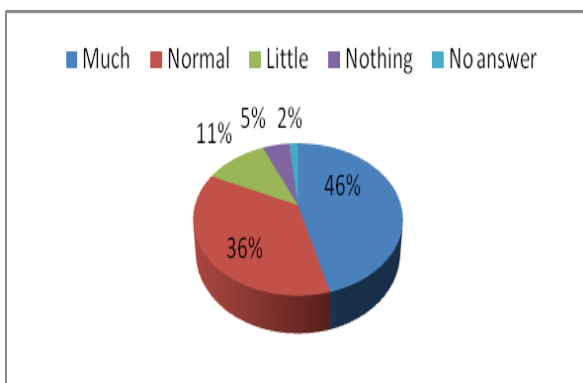


Figure 10: Answers to question 5.1.

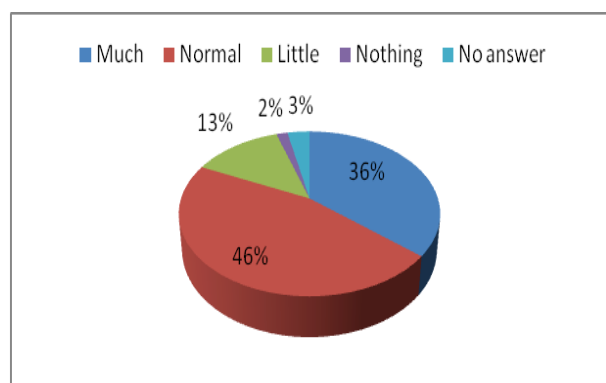


Figure 11: Answers to question 5.2.

### 3.2 Server usage

This section analyzes usage patterns for different types of course materials for autonomous learning for students enrolled in the courses. The data has been gathered for one semester, from Sept .2012 to Feb. 2013, gathered from the Moodle server.

The study of usage patterns by category (Figures 12 and 13) reveals that the contents that students find most useful for autonomous learning are the questionnaires, which includes the visualization of questionnaires, their resolution, and further retries to correct errors. This category gathers the highest

number of hits in both courses: a 38% of hits for Chemistry Degree (FIIQ) and 60% from the total number of accesses to the platform for Biology Degree (IAB). The second most successful activity is "self-evaluation slides", with 19% and 15% of hits, respectively. Screencasts visualization computes a 5% and 3% of the total number of accesses to the platform for FIIQ and IAB. These results show that the students have mainly opted for activities for autonomous evaluation. We can see that the trend is to obtain information from teachers during classes, and then use the platform as a vehicle to measure their level of understanding of the contents learned. Also, we can see the lack of interest of students for social communication channels available at the platform, such as the forum and the blog. This is due to the widespread use among students of other external social communication tools that replace the functionality of the platform.

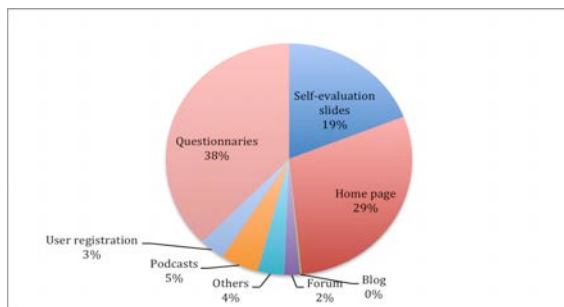


Figure 12: Server usage per module in FIIQ.

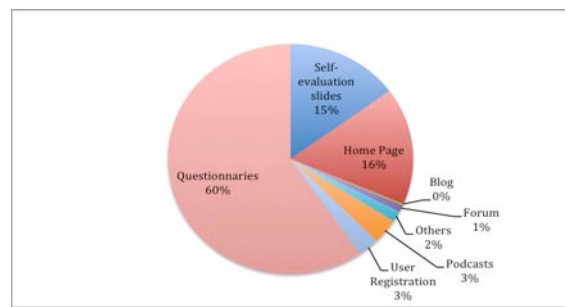


Figure 13: Server usage per module in IAB

As can be seen in Figure 14, for both courses the behavior regarding the use of course materials differs substantially. While students of IAB dedicate a similar amount of time for each lesson, FIIQ students are more interested in the module "Introduction to Excel". It is also notable how the module "Programming in Matlab" has a significantly higher number of hits for IAB.

With respect to the visualization of screencasts, Figure 15 shows how the students of IAB performed a number of hits similar for each resource, while in FIIQ students focused on three particular screencasts. Also, it is noteworthy that two of these screencasts are dedicated to Octave, an Open Source product. The remaining screencasts are devoted to describe Matlab, a proprietary software product.

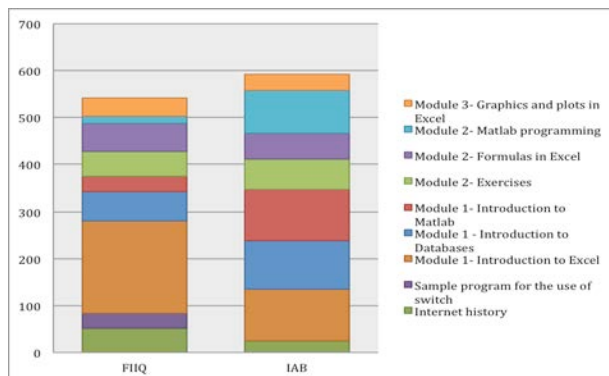


Figure 14: Access to self-evaluation.

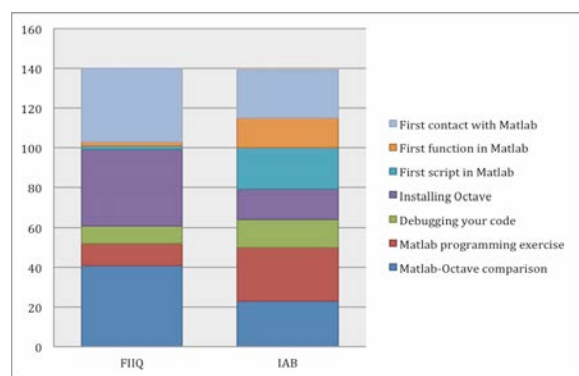


Figure 15: Postcast visualizations

Figure 16 shows that IAB students have worked more with the evaluation material, and have paid special attention to the lesson for Databases. Analyzing the charts globally we can see that FIIQ students have shown less interest in materials related to Matlab. IAB students have spent almost the same amount of time working with the different lessons.



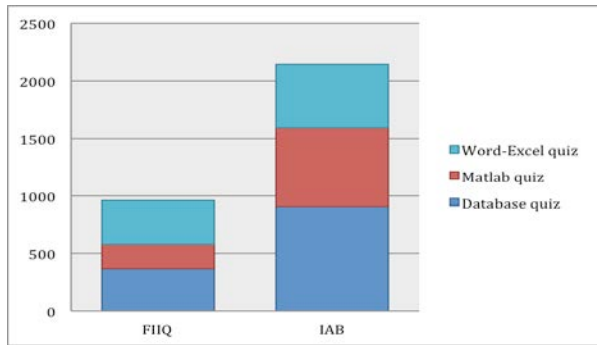


Figure 16: Access to questionnaires

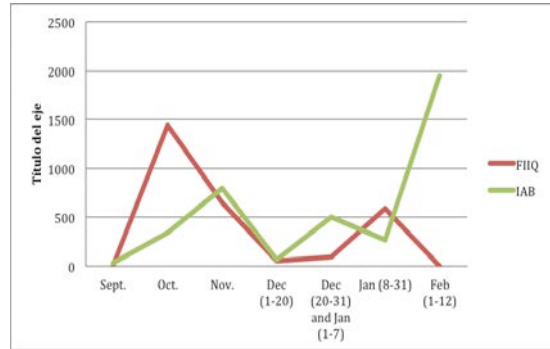


Figure 17: Evolution of access along time

With respect to the evolution of the accesses with time, Figure 17 shows that students have made a continued use of the platform. However, we observe that there is a very sharp decline in the week from Dec. 1st to Dec. 20th, the last week before the Christmas holidays. Although it should be noted how during the holiday period the number of hits increases. Also it is noteworthy the different behavior in the trends for both groups, while the number of hits for FIIQ decreases near the date of the final exam, in IAB increases to maximum levels. In general, access by students of IAB to the platform has been more constant.

Finally, the number of activities performed by users on the Moodle platform according to the location of the computer from which they access the platform shows that this is mainly accessed from outside the University of Granada. This fact confirms that the autonomous learning and evaluation materials are being used by the students for autonomous work at home.

### 3.3 Comparison of students results

In this section we aim to compare the effectiveness of these presented resources according to the students' final marks in the subjects where the extra material was offered. For that we compare the marks obtained in two consecutive years 2011/2012 versus 2012/2013 (academic course where the material was available). Spanish universities use the following 4-point scale for final qualifications: "Matrícula de Honor": 4; "Sobresaliente": 3, "Notable": 2 and "Aprobado": 1. We add a fifth label "Suspenso", with 0 as associated value, meaning that the student has not passed the subject.

Figures 18 and 19 show respectively the obtained results during the two consecutive years, 2011/2012 and 2012/2013, in every group (two groups of FIIAQ and three of IAB) in the two degrees. Each group is imparted by different professors but the same professor in both years. In Figure 3, we can observe that the marks averages are higher in some cases but lower in other groups. In addition it seems that the tendency of the marks is to increase when we focus on those students that pass the subject. Maybe this is due to the fact, that the extra material facilitated to the students has been used overall in those students having higher marks, and because of that we observe an increase on the number of students obtaining "Sobresaliente" or "Matrícula de Honor".

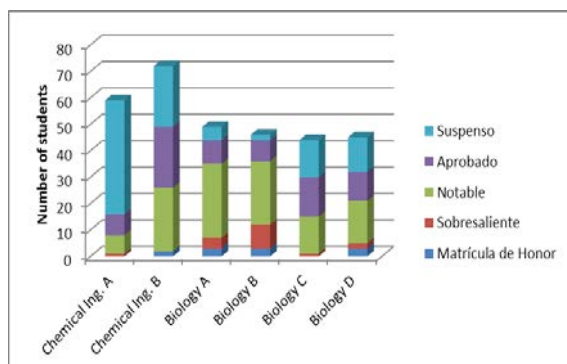


Figure 18: Results during the 2011/2012 course

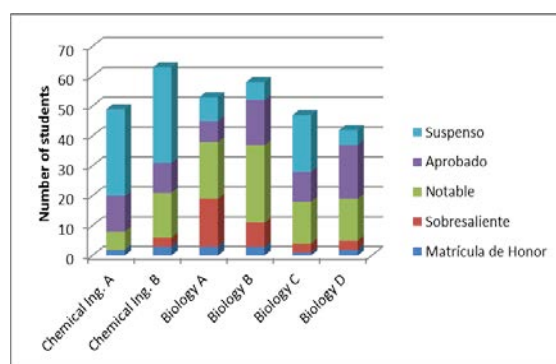


Figure 19: Results during the 2012/2013 course

## 4 CONCLUSIONS

In this paper we have presented an innovation project focused on autonomous work and framed in two subjects about Computer Science foundations in Science degrees. The project is based on a set of tools that promotes the students' autonomous work: Interactive questionnaires, self-assessments questions and screencasts. After an evaluation with several facets (surveys, server usage and comparison of qualifications) on several groups of these subjects, we conclude that these tools are useful for the students as they reinforce their learning process with additional learning elements out of the classical lecturers. We have supported this main conclusion on the facts that the overall students' perception of the utility of these tools is quite high, the objective data related to the server usage offer a good number of accesses to the web platform where these material were stored, and finally, a clear piece of evidence that they are working for the purpose by which they have been designed, the students' qualifications have improved from last course, where they did not use them, to this course, where the tools were available.

These good results motivate us, more if possible, to keep working harder in the application of new methodologies based on IT to the teaching and learning process, as we think that a correct way to motivate the student and make them get a much better learning performance.

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