International Journal of Engineering Education Vol. 29, No. 4, pp. 891–903, 2013
Printed in Great Britain
0949-149X/91 $3.00+0.00

Two New Moodle Modules for the Enhancement of a Problem-Based Learning Approach*

JOSEP M. MATEO-SANZ
Departament d'Enginyeria Quimica, Escola Tècnica Superior d'Enginyeria Química, Universitat Rovira i Virgili. Spain
E-mail: josepmaria.mateo@urv.cat

CARME OLIVÉ and DOLORS PUIGJANER
Departament d'Enginyeria Informàtica i Matemàtiques, Escola Tècnica Superior d'Enginyeria, Universitat Rovira i Virgili. 43007 Tarragona, Catalonia, Spain. E-mail: carme.olive@urv.cat, dolors.puigjaner@urv.cat

This paper describes two new Moodle modules that were developed to enhance a problem-based learning approach. One of the modules offers the possibility to easily customize student assessment. In particular, it enables the creation of questions containing random numeric variables, either scalar or vectorial, and whose answers are automatically computed regardless of the complex combination of numerical and logical operations involved in their calculation. The other module facilitates the subdivision of a problem into a common statement and a set of questions which are successively displayed in the browser. By combining these two modules, instructors can easily offer their students the opportunity to practice answering individualized quizzes anywhere and anytime. The analysis of the effect of the use of these two modules on students' performance revealed the existence of a strong link between the amount of online problems answered by students and their final grades. Typically, higher final grades were associated to higher regularity in answering individualized online problems. Moreover, it was shown that the use of individualized assessment quizzes tends to reduce academic dishonesty.

Keywords: problem-based learning; blended learning environments; Moodle modules; Statistics; academic dishonesty; constructivist learning

1. Introduction

An increasing number of students worldwide are seeking for a more convenient and cheaper education. This phenomenon has encouraged higher education institutions to explore the application of Information and Communication Technologies (ICT) in the design of their programs. Numerous investigations have focused on analyzing the diverse uses of ICT in the learning process from a pedagogical and psychological perspective [1–5]. Hybrid learning approaches that combine face-to-face teaching with some ICT supported activities and with some ICT mediated interactions between peers or between students and teachers are known as blended learning. Since ICT tools enables students to work at their own pace and to receive immediate feedback, their use within a blended learning context contributes to flexibility of learning. Thus, blended learning tools have generated considerable recent research interest (see [6–13] for example).

In most blended learning approaches, ICT are used within constructivist frameworks. The constructivist learning theory is based on the idea that learners construct knowledge by forming productive new links to their prior relevant learning experiences [14–16]. Within the constructivist learning environment, the teacher role changes from being the one who delivers the information to being a mentor, a consultant and a coach that helps students to understand concepts, to make connection among different concepts and to build their reasoning skills. According to Taber [17], an effective constructivist environment is neither teacher-centered nor student-centered but rather it is focused on the interaction of the student with the teacher and with peers. A detailed assessment of the educational effectiveness and constructivist orientation of several ICT can be found in [18].

The expanding use of ICT in education has numerous advantages; however, it also presents several drawbacks. In particular, since it is often easier to cheat on an online environment, the use of ICT in assessment tasks may increase acts of academic dishonesty. It is widely recognized that the problem of academic dishonesty is a widespread issue at both medium and high educational levels [19–21]. However, according to Carpenter et al. [22], engineering students are among the most frequent cheaters. Specifically, these authors reported that engineering undergraduates cheat almost twice on exams and homework than students from social sciences. Reduction of cheating and plagiarism has become a fundamental and challenging issue [23]. Numerous studies that focus on academic dishonesty incorporate recommendations to reduce cheating rates (see [22, 24–26] for example). Most of these studies point out the design of assessment tasks that reduce opportunities for cheating as an important issue in the prevention of academic dishonesty.

* Accepted 12 April 2013.

In a recent study [27], the use of ICT in the design of a blended learning methodology is reported. The methodology described therein is based on the subdivision of complex problems into simpler and shorter questions that guide students to the correct solution of the problem. The authors assessed the methodology in terms of students' satisfaction and motivation and they showed that both students' satisfaction and students' motivation increased when the methodology was applied within a Statistics course. It is worth noting that although the methodology was developed in the context of a Statistics course, it is suitable to teach any subject whose knowledge is related to solving-problem skills. However, a good performance of this methodology requires the finely subdivided problems to be delivered through a web-based platform verifying the following requirements:

1. It allows to present those questions conforming a problem in a progressive way, that is, a new question should not be displayed in the browser until the current question has been properly answered.
2. It can be configured so that after a fixed number of wrong answers to the same question, the correct solution is provided to the student. Otherwise, the student could remain stuck in a specific question.
3. Random numerical variables, either scalar or vectorial, can be easily introduced in question statements.

Note that if the web-based platform fulfilled the third requirement then individualized online assessment quizzes could be easily generated.

In order to achieve a good implementation of the methodology described in [27], the authors used a tailored web-based software. However, that software had the handicap that to access it from Internet required a secure shell tunneling protocol. The need of this rather high technological skill prevented a considerable number of students to use it regularly. The purpose of this study is to describe and analyze two new ICT tools that have been developed to facilitate the implementation of this blended learning approach by using the online learning platform called Moodle (Modular Object-Oriented Dynamic Learning Environment). Among the free online learning platforms, Moodle is one of the most commonly used by learning communities worldwide (see section 2.1 for further details about Moodle). However, Moodle does not fulfill the requirements needed to achieve a good implementation of the methodology described above. The ICT tools developed in the current study consist of two new Moodle modules that provide solutions to all the drawbacks of using Moodle to implement this methodology.

We aim to investigate whether the academic dishonesty is reduced with the use of individualized assessment quizzes. Furthermore, it is also the objective of this study to analyze the effect of the implementation of these two Moodle modules on students' performance. This analysis is conducted within the context of a Statistics course.

The rest of the paper is organized as follows. Section 2 is devoted to describe the two new Moodle modules in detail. Section 3 reports some data on students' performance and finally, the main conclusions are summarized in Section 4.

2. Description of the developed modules

With the purpose to let Moodle fulfill the three requirements listed in Section 1, we developed two new Moodle modules, which were called Programmed Responses and Guided Quiz, respectively. In particular, the Quiz module allows Moodle to satisfy first and second requirements whereas the third requirement is fulfilled when the Programmed Responses module is added to Moodle. Both modules were designed according to Moodle philosophy and Moodle coding guidelines.

2.1 Overview of Moodle features

Moodle is a Course Management System designed to help educators to create effective online learning sites. It is provided freely as Open Source software under the GNU General Public License and it has become one of the most commonly used Course Management Systems among learning communities worldwide. Moodle is based on a social constructivist framework of education [14–16] and its basic structure is organized around courses where learning resources and activities are presented to students. The set of privileges of a particular user in Moodle depends on the specific role (editor teacher, non-editor teacher, student, invited guest, etc.) of that user at each individual course. That is, users do not log in as teachers or students but their role is assigned as soon as they enter a specific course. Typically, the layout of the main page of a course displayed through Moodle includes a central part, where resources and activities are shown, and several side blocks which offer extra information or control features, as shown in Fig. 1.

Moodle has a modular structure. Thus, each activity or control element is provided through what is called a module. The Moodle Kernel contains several basic modules, such as the forum activity, the quiz activity, the assignment activity, the course administration feature or the calendar, among others. This modular structure has facili-

Fig. 1. Layout of the main page of a course displayed through Moodle.

tated the development of a great number of additional contributed modules which can be downloaded from the Moodle plugins directory in [28]. The quiz activity module is of particular interest in the current study because it is the one used to design and build quizzes consisting of different question types. The Moodle kernel provides users with a great variety of question types that include multiple choice questions, short answer questions or numerical questions, among others (see [29] for a description of all standard question types). It is worth noting that all the questions generated within Moodle are kept in what is called the Question bank. Consequently, Moodle offers the advantage of allowing questions to be re-used in several different quizzes.

2.2 The programmed responses module

Programmed Responses is a new Moodle question type that offers the user the possibility to create questions whose statements contain random variables and whose answers are automatically generated regardless of the complex combination of logical and numerical operations involved in their calculation.

2.2.1 Main features

The distinctive characteristics of the Programmed Responses question type can be summarized as:

- The text of the question can include numerical variables that are replaced with random values when the quiz is taken.
- The numerical variables included in the text of the question cannot be only scalar but also arrays.
- Several scalar numerical variables, which have been generated in an independent way, can be joined together into an array variable by using a concatenation operator. This property is particularly useful whenever an array, whose elements must follow different criteria, is required.
- Question's answer is provided by a set of editable, non-native PHP functions that are associated to the question.
- Question's answer can comprise several values.
- Questions can not be randomly selected when a quiz is generated.

These characteristics make this new question type specially suitable for both, problems whose solution can not be obtained from a single mathematical formula, and problems whose answer consist of one or more values. Both types of problems are found, for example, in statistical hypothesis testing.

Multiple versions of a question, which differ in their numerical values, can be created at once by using the programmed response question type. Thus, the numerical values of a programmed response question are likely to be different from one student to another and even within multiple attempts of the question by a particular student. This is so because the numerical values of each

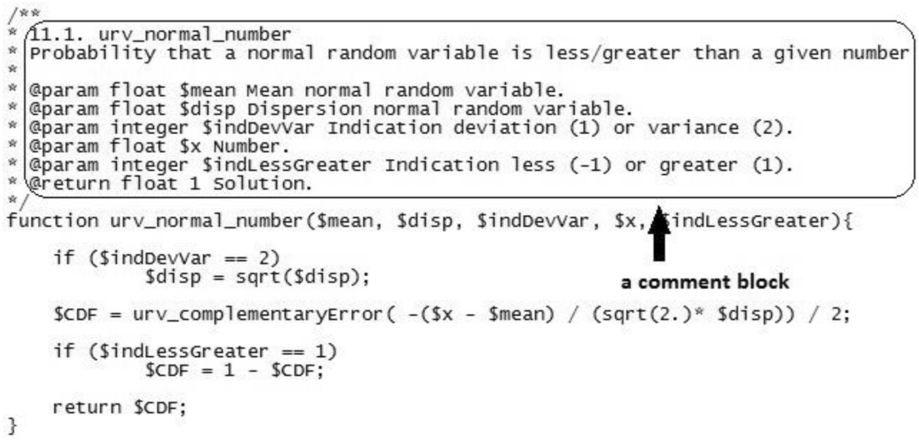

Fig. 2. An example of a PHP function.

variable are randomly generated automatically from a uniform distribution, each time Moodle delivers the question. For each numerical variable, the lower limit, the upper limit and the desired precision of the numerical values that would be accepted must be specified. If we denote by a, b and d, respectively, the lower limit (minimum), the upper limit (maximum) and the precision (increment) of a numerical variable, then the numerical values of this variable will be randomly chosen uniformly from values of the form $a+kd$ with $0 \leq k \leq (b-a)/d$, being k a natural number. For example, if $a = 0$, $b = 0.6$ and $d = 0.15$, the numerical variable would randomly take the values 0, 0.15, 0.30, 0.45 and 0.6. In case of an array variable, the number of scalar values included in the array must also be specified.

Answers to programmed response questions are also automatically generated from non-native PHP functions associated to each question. All the arguments of a PHP function associated to a question must be properly linked either to a defined variable, a concatenation of defined variables or a fixed value in the question statement (see Subsection 2.2.2 for an example). In order to encourage the addition of non-native PHP functions, we have designed and implemented a user interface that allows the user to easily upload PHP functions to the Moodle platform. All PHP functions uploaded to the Moodle platform should include a comment block similar to that shown in Fig. 2. This comment block must contain a brief description of the purpose, the arguments and the returned values of the function. It must be written according to the phpdoc format.

At first sight, it can be thought that the programmed response question type is very similar to the calculated question type provided by Moodle kernel. However, there are significant differences between both question types, as it is shown in Table 1.

2.2.2 *Examples of use*

In the following, we provide three examples to elucidate the possibilities of the Programmed Responses module. The Moodle screen shot shown in Fig. 3 illustrates the student's view of a programmed response question whose answer is not a single value but it comprises a pair of numbers.

Table 1. Main differences between programmed response questions and calculated questions

Item	Calculated Question	Programmed response Question
Type of accepted variables	Scalar	Scalar and Arrays
Generation of random values	A list of at most 100 values for each numerical variable is generated once and then only values within the list are randomly used	Values for the numerical variables are automatically generated each time Moodle delivers the question to a student
Number of values in the Answer	Only one value	One or more values
Type of accepted answers	Numerical	Numerical and Character Strings.
How the answer is calculated	Through one formula that can contain arithmetic operators and some mathematical functions	Through a set of editable non-native PHP functions that can contain any kind of operators and functions

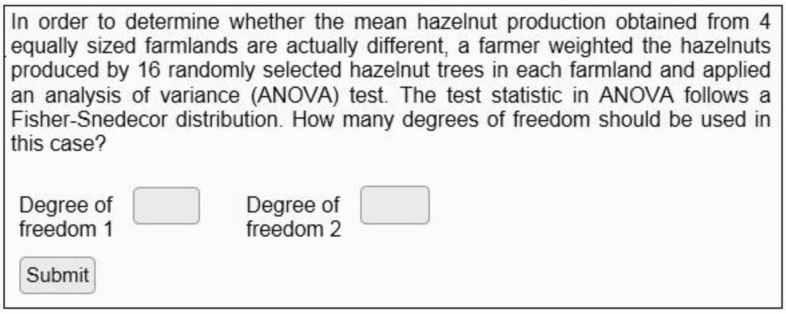

Fig. 3. An example of a programmed response question whose answer requires two numerical values.

For the second example we consider the following question:

Assuming that the attained p-value in a hypothesis test is {$pvalue} and using a level of significance {$error}, should the null hypothesis be rejected? (Answer 1 if there is enough evidence to reject the null hypothesis, and 0, otherwise).

Note that names within braces and preceded by the $ symbol, such as *pvalue* or *error,* correspond to numerical variables whose values are randomly assigned each time the question is attempted. The editable, non-native PHP function that provides the answer to this question is shown in Fig. 4. This figure shows that a logical operation is involved in the answer.

Finally, the following statement exemplifies a question whose answer requires a rather complex combination of numerical and logical operations.

The scores on a civil service exam are normally distributed with a mean of {$mean} and a standard deviation of {$stdev}. What is the probability that a person randomly selected among those that take the exam gets an exam mark lower than {$number}?

The answer to this question is provided by the PHP function shown in Fig. 2. In order to enlighten the creation procedure of programmed response questions, the main steps in the generation of the latter question are summarized in Fig. 5 and Fig. 6. First steps are shown in Fig. 5 and they consist of the edition of the question statement, the choice of the properties of the numerical variables, if any, and the selection of the PHP function that provides the answer.

In the next step, each of the arguments of the PHP function are either assigned a fixed value or linked with either a numerical variable or a concatenation of numerical variables in the statement of the question, as detailed in Fig. 6. Furthermore, when the programmed response question is included into a guided quiz (see Section 2.3), arguments in the PHP function can also be linked to numerical variables which arise in the guided quiz but are not present in the statement of the question. In such situation, the option Guided quiz in Fig. 6 must be selected.

2.3 The guided quiz module

The Guided Quiz module is a new module that adds several features to the standard Moodle quiz module. The additional features allow the user to easily generate problems consisting of a common statement and several questions that are sequentially displayed to the student. Usually, subsequent

```
/**
* 35.3. urv_ht_conclusion
* Conclusion in hypothesis testing.
*
* @param float $error Level of error
* @param integer $indover100 Indication error probability (1) or percentage (100)
* @param array $pvalue p-value
* @return float 1 Solution
*/
function urv_ht_conclusion($error, $indover100, $pvalue){

    $error /= $indover100;

    $result = 0;
    if ($pvalue <= $error)
       $result = 1;

    return $result;
}
```

Fig. 4. Editable, non-native PHP function involving logical operations.

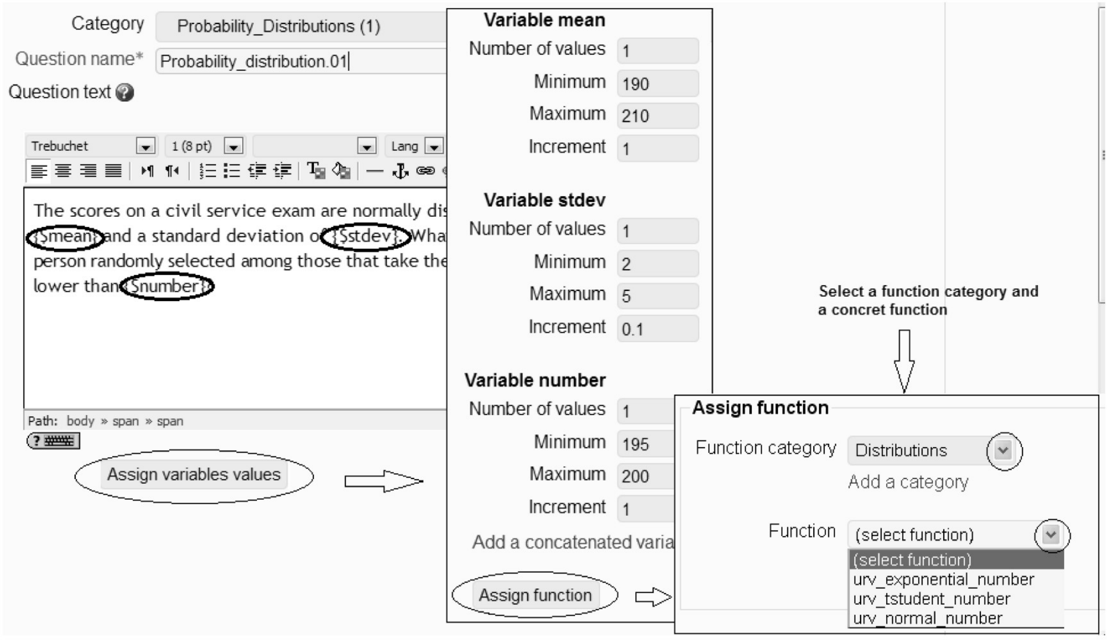

Fig. 5. Screen shot showing the three first steps in the creation procedure of a programmed response question: statement edition, choice of the properties of the numerical variables, if any, and assignment of the PHP function that provides the answer.

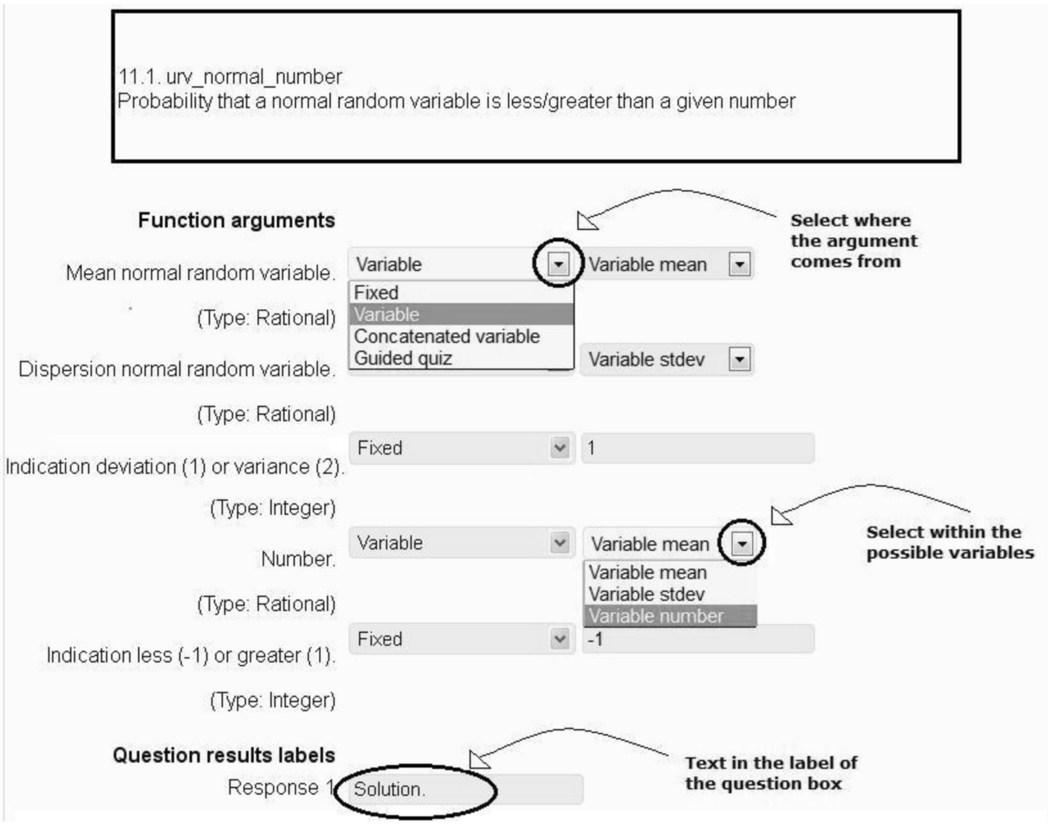

Fig. 6. Screen shot showing the user interface designed to assign values to the arguments of the chosen PHP function in a programmed response question.

questions are related with the common statement, although it is not compulsory.

2.3.1 *Main features*

The main characteristics that differentiate a Guided Quiz from a standard Quiz can be summarized as:

- In addition to a set of questions, it can contain a common statement. The common statement does not require an answer but it is included in the quiz in order to deliver relevant information to which some questions within the quiz may refer to.
- The common statement is only shown when the quiz is attempted and it is always displayed along with any subsequent question.
- The set of questions included in the quiz are not displayed all at once but they are sequentially displayed.
- A new question is delivered only when one of the following three conditions holds
  - the current question has been rightly answered;
  - the maximum number of allowed attempts defined for that question has been reached;
  - the "skip to next question"—button has been clicked.
- A maximum number of allowed attempts and a penalty factor for each wrong attempt can be defined for each question within the context of a particular guided quiz.
- The teacher can determine whether answered questions are shown or hided when a new question of the quiz is displayed.
- The teacher can decide whether right answers of those questions previously answered or skipped are displayed or not.
- It is not allowed to randomize the order in which questions are displayed within a quiz.
- Numerical variables are also allowed to be present in the common statement of a guided quiz. Their definition and operating mode coincide with those described for programmed response questions.
- Numerical variables included in a guided quiz can be either global or local. Global variables are accessible from every question within the quiz, regardless of where they are defined. Local variables are only available within the programmed response question wherein they are defined. All the numerical variables contained in the common statement of a quiz are global variables.

The characteristics of the Guided Quiz module make it very useful to subdivide a complex problem into a set of sequentially presented smaller questions. The suitable division of problems into smaller questions that guide students to the right problem's answer provides students with a clear structure that facilitates a better understanding of the concepts and procedures involved in their solution.

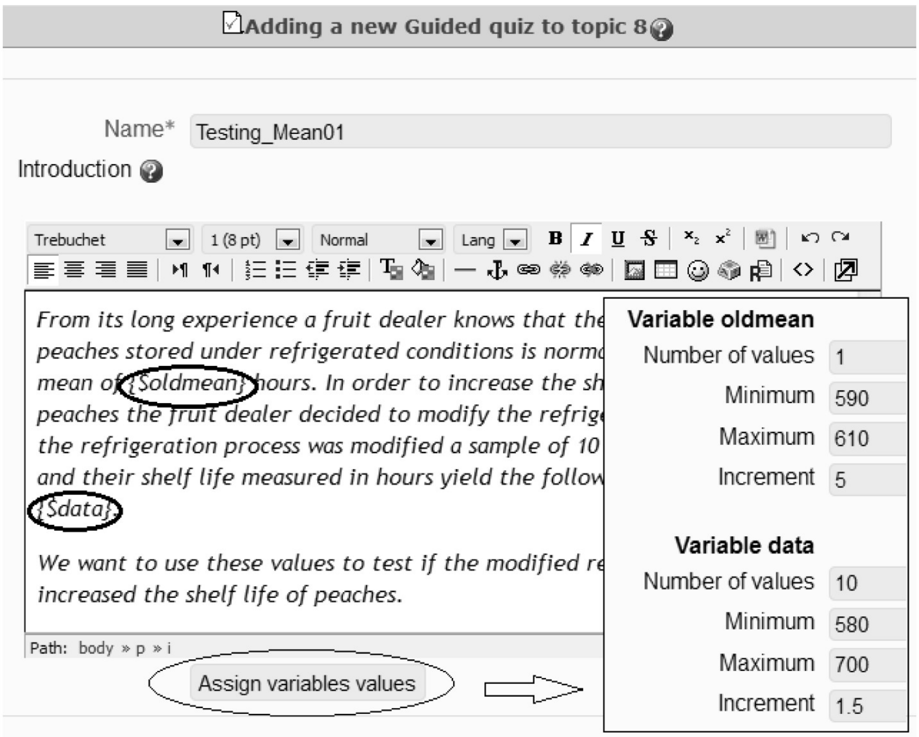

Fig. 7. Screen shot summarizing the two first steps in the creation procedure of a guided quiz: edition of the common statement and choice of the properties of the numerical variables contained therein.

Notwithstanding, as students improve their skills to tackle problems, they progressively need less guidance. Guided quizzes have the advantage that they can be configured so that they behave in different ways. They can provide students with right answers and/or grades as the quiz is taken, or alternatively, it can be configured so that neither answers nor grades are revealed to students until the whole quiz is finished. Hence, the versatility of the Guided Quiz module allows the teacher to easily adapt guided quizzes to different learning stages and even to use it for assessment purposes.

2.3.2 Example of use

Fig. 7, Fig. 8 and Fig. 9 summarize the creation of a guided quiz with the following common statement:

> *From its long experience, a fruit dealer knows that the shelf life of fresh peaches stored under refrigerated conditions is normally distributed with a mean of {$old-mean} hours. In order to increase the shelf life of fresh peaches, the fruit dealer decided to modify the refrigeration process. After the refrigeration process was modified, a sample of 10 peaches was selected and their shelf life measured in hours yield the following results {$data}.*
> *We want to use these values to test if the modified refrigeration process increased the shelf life of peaches.*

And the following set of questions:

(a) *Which kind of hypothesis test should be applied?*
(b) *Which is the value of the sample test statistics?*
(c) *Which is the attained p-value?*
(d) *According to the p-value and using a level of significance {$level}, is there enough evidence to conclude that the modified refrigeration process increases the shelf life of peaches? (Answer 1 if there is enough evidence, and 0, otherwise)*

The creation of a guided quiz is quite similar to the creation of a standard quiz. However, it presents some particularities. The first particularity arises when the settings of the quiz are displayed. In the guided quiz, the common statement must be written in the place reserved to an introduction for the standard quiz. In order to be able to introduce the properties of the numerical variables contained in the common statement, a new box has been included in the quiz administration tab, as it can be observed in Fig. 7. The assignment of values to the arguments of the PHP function that provides the answer to a question in this quiz is displayed in Fig. 8.

Note that two of the arguments are linked to numerical variables that are not included in the question but in the common statement of the

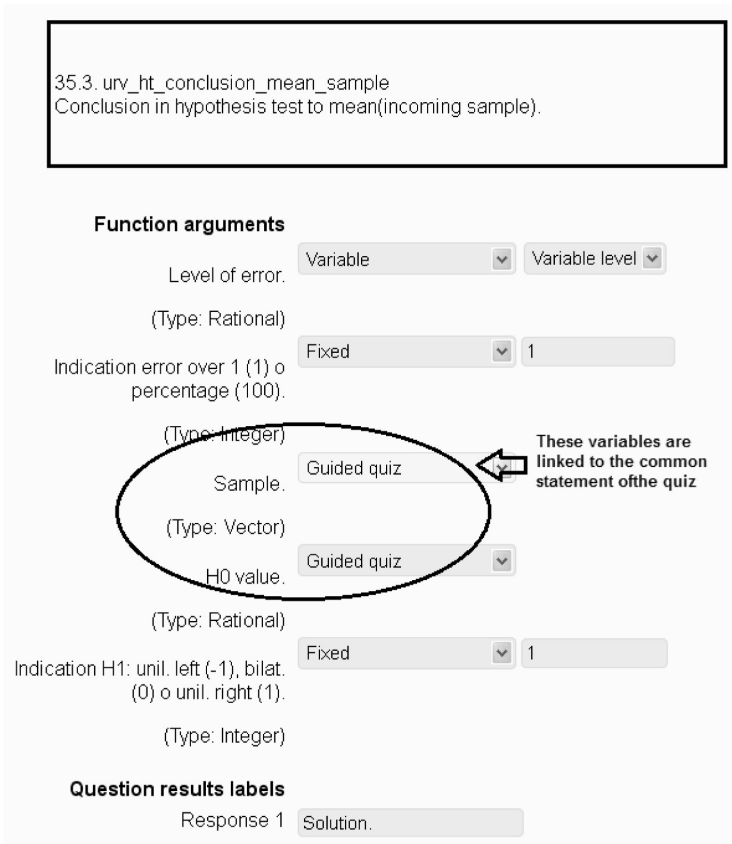

Fig. 8. Screen shot showing how to link some arguments of the PHP function to the guided quiz.

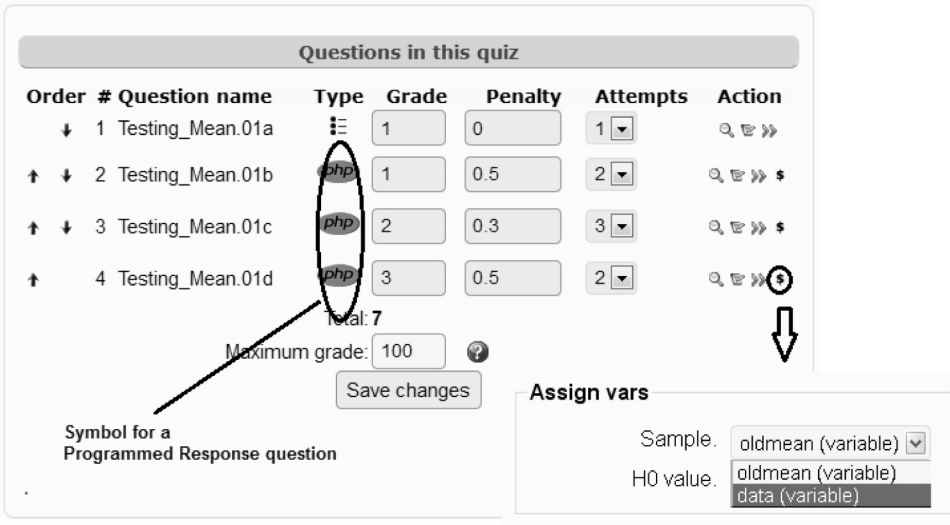

Fig. 9. Screen shot showing the assignment of variables to those arguments of a PHP function that have been linked to the common statement.

guided quiz. Fig. 9 shows the procedure to link these two arguments to the numerical variables in the common statement.

3. Results and discussion

The Programmed Responses module allows the automatic generation of multiple versions of questions which only differ in their numeric parameters. Thus, a different version of the same question can be easily distributed to each student when either assignment or assessment activities are delivered. Individualized assessment quizzes can therefore be easily generated by designing quizzes which are mostly composed of programmed response questions. Note that by using this kind of quizzes, we ensure that the difficulty of the assessment activity is the same for all the students. However, as questions differ in their numeric parameters, students can not share their answers and opportunities for cheating are reduced. Furthermore, since answers of programmed response questions are automatically generated, the time needed by teachers to prepare and grade this kind of assessment activities is fairly low.

It is worth noting that the addition of the current modules to a Moodle platform requires administration privileges. However, this is a minor limitation as it can be easily addressed by contacting the Moodle administrator. A more important drawback of these modules relates to the procedure used to generate answers to programmed responses questions. As it is explained in section 2.2.1 this procedure relies on non-native PHP functions, which must be coded and uploaded to the Moodle platform. Since the lack of PHP coding skills might prevent some people to use the Programmed Responses module, future work is planned to create a repository of PHP functions.

Some results related to the students' performance are analyzed within the context of a Statistics course. Further details about the context of the course are discussed in Section 3.1. In Section 3.2, we investigate if there is evidence to indicate that students tend to share their answers when the same online assignment is delivered to all students. Section 3.3 is devoted to study the existence of any relation between the amount of online problems answered by one student and his or her final grades.

3.1 Context of the course

The two new Moodle modules described in the present study were developed within the context of an introductory Statistics course taught at the Rovira i Virgili University in Catalonia (Spain). The course was designed to fit the needs of students enrolled in different engineering degrees. Its major topics include descriptive statistics, probability distribution functions, confidence interval estimation, hypothesis testing and linear regression. It was taught by using the problem-based learning approach reported in [27]. The method described therein is mainly based on three points:

1. The combination of face-to-face theory classes and online computer-aided practical classes.
2. The availability of a collection of problems which are finely subdivided into several smaller questions that progressively guide the student to their solution.
3. The use of a web-based platform to access the proposed problems.

This course is taught four hours per week along 15 weeks. Two hours per week are devoted to regular lectures at which special emphasis is put on helping students to understand concepts. The other two hours take place in a computer lab where students individually solve problems through the web-based platform. All these lab sessions are supervised by teachers. However, students work independently and only occasionally they get help from teachers. Problems solved during these lab sessions are graded on a scale from 0 to 10, whereby 10 denotes the highest grade and 0 the lowest. Before each lab session, students can practice anywhere and anytime in an individualized and flexible manner by accessing the collection of problems available through the web-based platform. At the end of the course, each student receives a lab grade which is calculated as the arithmetic mean of the grades obtained on the problems solved through the online platform during the lab sessions. The course assessment is obtained from the average of the lab grade and the grade obtained in a traditional paper-and-pencil final exam. Note that grades obtained on the problems solved online outside lab sessions are not taken into account for the course assessment.

3.2 Effect of individualized quizzes on academic dishonesty

As mentioned in the previous section, students enrolled in the Statistics course receive two grades: one grade is obtained from the final traditional paper-and-pencil exam, and the other one reflects the student's performance at the practical classes. The latter is determined as the average of the grades obtained on the problems solved through the online platform during the lab practical classes. It seems reasonable to assume that, in the absence of academic dishonesty, both grades are highly related. Our hypothesis is that, in the absence of academic dishonesty, there is a linear relationship between the lab grade and the final exam grade. A lack of linear relationship on the two grades will be read as an indication of a possible academic dishonesty. Given a particular class group, it was our aim to statistically validate or reject our hypothesis within that group. Hence, we used a linear regression statistical hypothesis test to determine whether there was a significant linear relationship between the independent variable (lab grade) and the dependent variable (final exam grade). We analyzed the relationship between the two grades, final exam grade and lab grade, in class groups within the following two contexts:

- Context A (before the individualized quizzes were available): in this context, all students must answer exactly the same online quizzes during practical lab sessions.
- Context B (after the individualized quizzes were available): in this context, the numeric parameters in the questions comprising the online quizzes take random values and they are consequently different from one student to another.

The study was carried out with eleven class groups, five within context A and six within context B. The instructors and studied topics were the same in the eleven groups.

The results of the regression statistical hypothesis test for each group are shown in Table 2. This table contains the p-value of the test, the Pearson linear correlation coefficient, r, and the size of the group n. Note that a p-value lower than 0.05 indicates that we can assume a linear relationship between lab grades and final exam grades with a 95% level of confidence. We observe in Table 2 that all class groups within context B have p-values lower than 0.05, whereas within the context A only two of the five analyzed groups have p-values lower than 0.05. These results indicate that the use of individualized online quizzes during the lab sessions tends to reduce academic dishonesty within our Statistics course.

3.3 Effect of the use of the two new modules on students' performance

The two new modules have been extensively used since the academic year 2011–12. During such academic year, there were eighty-nine students enrolled in the Statistics course. As our students had an easy access to the Moodle environment, we offered them the chance to practice beforehand those questions included in the assessment quiz that would be delivered at the next lab practical session. These questions were available during the two days prior to the lab class. In the current section, we study the effect of the quantity of questions answered online during the two days prior to the lab classes on both the students' lab grades and the students' final exam grades. We are interested not in the absolute number of answered questions but in the ratio of the number of answered questions to the

Table 2. Results of the linear regression statistical hypothesis test.

Group	Context	p-value	r	n
1	A	0.3431	0.1118	74
2	A	0.1916	0.1724	59
3	A	0.0043	0.3666	59
4	A	0.0270	0.3970	31
5	A	0.3810	0.1722	28
6	B	0.0034	0.5436	27
7	B	0.0233	0.4274	28
8	B	0.0031	0.4263	46
9	B	0.0438	0.3089	43
10	B	0.0011	0.3455	86
11	B	3.03E-06	0.5188	72

total number of available questions. Let PQ denote the percentage of questions answered. We classified the students in the following five categorical groups:

- Categorical group 0: students with PQ < 10%
- Categorical group 1: students with 10% $\leq$ PQ <25%
- Categorical group 2: students with 25% $\leq$ PQ <50%
- Categorical group 3: students with 50% $\leq$ PQ <80%
- Categorical group 4: students with PQ $\geq$ 80%

and we performed two one-way ANOVA tests. One-way ANOVA test is a statistical hypothesis test used to determine whether the mean of a variable is affected by one factor or treatment or not. In our case, the factor or treatment was the percentage of questions answered, and we investigated two variables, namely the lab grade and the final exam grade. The p-value obtained when the variable considered was the lab grade (final exam grade) was 2.62E-11 (2.46E-08). From these extremely low p-values, we conclude that the number of answered questions during the two days prior to lab classes has a significant effect on both the lab grades and the final exam grade. Therefore, the ANOVA test results reveal that not all the five groups have the same mean.

In order to identify which groups in the sample differ, we applied a Tukey's HSD (honestly significant difference) test. This test compares the mean of every treatment to the mean of every other treatment. The results of the test when the variables investigated are the lab grade and the final exam grade are presented in Table 3 and Table 4, respectively. These tables show that whereas there are not significant differences between consecutive groups, the differences between groups that are not consecutive are significant. It can also be observed in Tables 3 and 4 that as the percentage of answered questions is decreased, both the lab grade and the final exam grade are dropped. Therefore, it may be concluded that answering online questions regularly helps students to be proficient in the contents of the course.

Table 3. Results of the Tukey's HSD test when the analyzed variable is the lab grade

Categorical Group	Mean	Homogeneous Groups			
4	9.65	A			
3	8.77	A	B		
2	8.41		B	C	
1	7.72			C	D
0	7.34				D

Table 4. Results of the Tukey's HSD test when the analyzed variable is the final exam grade

Categorical Group	Mean	Homogeneous Groups			
4	7.60	A			
3	5.48	A	B		
2	4.68		B	C	
1	3.02			C	D
0	2.52				D

3.4 Discussion

The Programmed Responses module enables the creation of questions whose statements include random numerical variables and whose answers are automatically generated regardless of the complex combination of numerical and logical operations involved in the calculation. Thus, this module offers the possibility to easily customize student assessment by distributing a different version of the same question to each student. It is worth noting that questions generated with the Programmed Responses module differ significantly from the calculated questions provided by Moodle kernel. The most important difference relates to the procedure used to generate answers to questions. Whereas the answer to a calculated question comprises a single mathematical formula, the answer to a programmed response question is generated by a non-native PHP function that can contain any set of operators and functions. PHP coding skills are, therefore, needed to write those PHP functions involved in the generation of answers to programmed responses questions. In order to minimize the limitation posed by the need to code, future work will be oriented to develop an extensible repository where PHP functions could be downloaded and uploaded.

The Guided Quiz module facilitates the generation of problems consisting of a common statement and several questions which are successively displayed to the student. This module is very useful to finely subdivide a complex problem into a set of questions that progressively guide students to the right problem answer. By combining the Guided Quiz module with the Programmed Responses module instructors can easily offer their students the opportunity to practice answering individualized quizzes anywhere and anytime receiving immediate feedback.

Within the context of a Statistics course we have analyzed the effect of the use of these two new modules on two issues related to students' performance. First we have analyzed the effect of the use of individualized online assessment quizzes on the academic dishonesty. We have assumed that the lack of a linear relationship between lab grades and final exam grades within a class group implies the existence of academic dishonesty during the lab classes. Note that lab grades are determined as the average of the grades obtained from online quizzes answered during the lab classes. By means of a linear regression statistical hypothesis test we have found that a linear relationship between lab grades and final exam grades could be assumed, with a 95% level of confidence, in all the class groups where individualized quizzes were delivered during the lab classes. By contrast, the linear relationship between grades could be assumed only in 40% of the class groups were identical quizzes were used instead.

Finally, under the hypothesis that students have the opportunity to practice answering online questions anywhere and anytime, we have investigated the existence of a link between the amount of online questions answered by students and their grades. Results obtained from one-way ANOVA tests have revealed that the percentage of online questions answered by students has a significant effect on their grades. In addition, a Tukey's HSD test has shown that higher final grades are associated to higher percentage of online answered questions.

4. Conclusions

The existence of open-source Course Management Systems along with the widespread access to Internet have fostered the adoption of blended learning approaches. However, any Course Management System has some limitations that can complicate the implementation of some specific learning methodologies. In this paper, we have described two new Moodle modules that have been developed to facilitate the implementation through Moodle of a problem-based learning methodology. Although the modules were developed in the context of a Statistics course they are flexible enough to be suitable to teach any subject whose knowledge is related to solving-problem skills. Notwithstanding, this flexibility has its drawback: PHP coding skills are needed to achieve a high performance of the developed Moodle modules.

The effect of the use of these two modules on students' performance has been investigated by using statistical hypothesis tests. From our results two main conclusions are derived. First, the use of individualized online assessment quizzes tends to reduce academic dishonesty. Second, when students can practice answering individualized question anywhere and anytime receiving immediate feedback, a high regularity in answering these online questions help students to be proficient in the contents of the course.

Acknowledgments—The authors wish to acknowledge the professionals from the firm Mosaic Consultoria for their valuable work in the programming process of the Moodle modules. In particular, we would like to highlight the professional and personal excellence of its employee David Monllaó.

Josep M. Mateo-Sanz thanks the support of the UNESCO chair in Data Privacy. This work was partly supported by the Government of Catalonia under grant 2009 SGR 1135, by the Spanish Government through projects TSI2007-65406-C03-01 "E-AEGIS", TIN2011-27076-C03-01 "CO-PRIVACY" and CONSOLIDER INGENIO 2010 CSD2007-00004 "ARES", and by the European Commission under FP7 project "DwB". The authors are solely responsible for the views expressed in this paper, which do not necessarily reflect the position of UNESCO nor commit that organization.

Dolors Puigjaner thanks the financial support received from the Spanish Ministry of Education through project CTQ2008-04857/PPQ, and from the Government of Catalonia through project 2009SGR-1529.

References

1. A. W. Bangert, The seven principles of good practice: a framework for evaluating on-line teaching, *The Internet and Higher Education*, **7**(3), 2004, pp. 217–232.
2. A. M. Bliuc, P. Goodyear and R. Ellis, Research focus and methodological choices in students' experiences of blended learning and higher education, *The Internet and Higher Education*, **10**(4), 2007, pp. 231–244.
3. P. Goodyear, Pedagogical frameworks and action research in open and distance learning, *European Journal of Open and Distance Learning*, (online), http://www.eurodl.org/materials/contrib/1999/goodyear/, 1999, Accessed September 2012.
4. M. Limniou and M. Smith, Teachers' and students' perspectives on teaching and learning through virtual learning environments, *European Journal of Engineering Education*, **35**(6), 2010, pp. 645–653.
5. M. Khalifa and R. Lam, Web-based learning: effects on learning process and outcome, *IEEE Transactions on Education*, **45**(4), 2002, pp. 350–356.
6. D. Whitelock and A. Jelfs, Journal of Educational Media special issue on blended learning, *Journal of Educational Media*, **28**(2–3), 2003.
7. N. W. Heap, K. L. Kear and C. C. Bissell, An overview of ICT-based assessment for engineering education, *European Journal of Engineering Education*, **29**(2), 2004, pp. 241–250.
8. B. Allan, *Blended Learning: Tools for Teaching and Training*, London: Facet Publishing, 2007.
9. E. W. T Ngai, J. K. L. Poon and Y. H. C Chan, Empirical examination of the adoption of WebCT using TAM. *Computers & Education*, **48**(2), 2007, pp. 250–267.
10. T. Martín-Blas and A. Serrano-Fernández, The role of new technologies in the learning process: Moodle as a teaching tool in Physics, *Computers & Education*, **52**(1), 2009, pp. 35–44.
11. J. L. Cortizo, E. Rodríguez, R. Vijande, J. M. Sierra and A. Noriega, Blended learning applied to the study of Mechanical Couplings in engineering, *Computers & Education*, **54**(4), 2010, pp. 1006–1019.
12. E. Gutiérrez, M. A. Trenas, J. Ramos, F. Corbera and S. Romero, A new Moodle module supporting automatic verification of VHDL-based assignments, *Computers & Education*, **54**(2), 2010, pp. 562–577.
13. G. Lazakidou and S. Retalis, Using computer supported collaborative learning strategies for helping students acquire self-regulated problem-solving skills in mathematics, *Computers & Education*, **54**(1), 2010, pp. 3–13.
14. V. Burr, *An introduction to social constructionism*, London: Routledge, 1995.
15. H. J. Stam, Introduction: Social constructionism and its critiques, *Theory & Psychology*, **11**, 2001, pp. 291–296.
16. L. Moreno, C. González, I. Castilla, E. González and J. Sigut, Applying a constructivist and collaborative methodological approach in engineering education, *Computers & Education*, **49**(3), 2007, pp. 891–915.
17. K. S. Taber, Constructivism and the Crisis in U.S. Science Education: An Essay Review, *Education Review*, **12**(12), 2009.
18. C. R. Payne, *Information Technology and Constructivism in Higher Education: Progressive Learning Frameworks*, Hershey, PA: IGI Global, 2009.

19. R. L. Genereux and B. A. McLeod, Circumstances surrounding cheating: A questionnaire study of college students, *Research in Higher Education*, **36**(6), 1995, pp. 687–704.
20. G. Curtis and R. Popal, An examination of factors related to plagiarism and a five-year follow-up of plagiarism at an Australian university, *International Journal for Educational Integrity*, **7**(1), 2011, pp. 30–42.
21. F. Rosales, A. García, S. Rodríguez, J. L. Pedraza, R. Méndez and M. M. Nieto, Detection of plagiarism in programming assignments, *IEEE Transactions on Education*, **51**(2), 2008, pp. 174–183.
22. D. D. Carpenter, T. S. Harding and C. J. Finelli, Using research to identify academic dishonesty deterrents among engineering undergraduates, *International Journal of Engineering Education*, **26**(5), 2010, pp. 1156–1165.
23. J. Sheard and M. Dick, Directions and dimensions in managing cheating and plagiarism of IT students, *Proceedings of the Fourteenth Australasian Computing Education Conference*, Australian Computer Society, Sydney NSW Australia, 2012, pp. 177–185.
24. G. Cizek, *Cheating on Tests: How to Do It, Detect It, and Prevent It*, Mahwah, NJ: Lawrence Erlbaum & Associates, 1999.
25. L. McDowell and S. Brown, Assessing students: cheating and plagiarism. *The Higher Education Academy*, (online), http://www.le.ac.uk/teaching/assets/mcdowell_and_brown.pdf, 2001, Accessed September 2012.
26. N. C. Rowe, Cheating in Online Student Assessment: Beyond Plagiarism, *Online Journal of Distance Learning Administration*, **7**(2), (online), http://www.westga.edu/~distance/ojdla/summer72/rowe72.html, 2004, Accessed September 2012.
27. J. M. Mateo-Sanz, A. Solanas, D. Puigjaner and C. Olivé, Refining Statistical problems: a problem-based learning methodology to improve student's motivation, *International Journal of Engineering Education*, **26**(3), 2010, pp. 667–680.
28. Moodle plugins directory, http://moodle.org/plugins, Accessed September 2012.
29. Moodle documentation, http://docs.moodle.org/22/en/Questions, Accessed September 2012.

Josep Maria Mateo Sanz is an Associate Professor in the area of Statistics and Operational Research in the Department of Chemical Engineering at the Rovira i Virgili University. He received his Ph.D. in Mathematics from the University of Barcelona (UB). He is member of the CRISES research group (http://crises-deim.urv.cat) where he works on security and information privacy. His research interests are statistical disclosure control, security and data privacy, the application of statistics, and e-learning.

Carme Olivé is an Associate Professor in the Department of Computer Engineering and Mathematics at the Universitat Rovira i Virgili (URV), Tarragona, Catalonia, Spain. She obtained her Ph.D. in Applied Mathematics from the Technical University of Catalonia (UPC). She is a member of the Group of Dynamical Systems of UPC that conducts research on analytical and numerical methods for continuous and discrete dynamical systems and their applications to neuroscience, celestial mechanics and astrodynamics. Her research is directed at e-learning and at applying the Resurgence Theory to study exponentially small phenomena.

Dolors Puigjaner is an Associate Professor in the Department of Computer Engineering and Mathematics at the Universitat Rovira i Virgili (URV), Tarragona, Catalonia, Spain. She is a member of the Research Group on Transport Phenomena (FeT) that conducts interdisciplinary research on computational fluid mechanics, heat and mass transport, environmental engineering, computational sciences and dynamical systems. She received her PhD in Applied Mathematics from the Universitat de Barcelona (UB), Barcelona, Catalonia, Spain. Her research interests include Rayleigh-Bénard convection, efficient mixing, application of dynamical system tools to the study of fluid mechanics problems and e-learning.