

Computer Assisted Assessment through Moodle Quizzes for Calculus in an Engineering Undergraduate Course

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Abstract: The European Higher Education Area (EHEA) furthers a student-centered system based on the student workload required to achieve the objectives of a study program. In the context of EHEA, e-learning tools provide an outstanding opportunity to discuss mathematical activity in the 21st-century classroom. In 2002, the Technical University of Catalonia (UPC) undertook the use of a virtual teaching tool, the virtual campus Atenea. Since 2005 Atenea has been based on Moodle, an open source learning management system designed to help educators create quality online courses and administer learner outcomes. From the wide range of tools offered by Moodle, we are focusing on the quiz module. This module allows the creation of quizzes with different types of question, adapted to the specific objectives to be reached at any step in the teaching-learning process. Moodle quizzes contribute to the development of new strategies not feasible with paper-and-pencil tests. To explore how to apply these new strategies in the development of a substantial bank of quiz questions, we are carrying out projects subsidised by the Institute of Education Sciences of the UPC. This contribution focuses on the assessment of three Moodle quizzes for Calculus topics that were designed to be answered by around 70 first-year students of the School of Civil Engineering (UPC) in the course 2007/2008. In particular, the aims are to analyse students' answers and to carry out a psychometric analysis to identify the appropriateness of the questions stated in the quizzes.

Résumé: L'Espace Européen d'Éducation Supérieure (EEES) favorise un système centré sur l'étudiant, basé sur le travail nécessaire pour atteindre les objectifs d'un programme d'étude. Dans le contexte de l'EHEA, les outils d'apprentissage en ligne (*e-learning*) offrent une bonne opportunité pour réfléchir à l'activité mathématique dans la classe du 21^{ème} siècle. En 2002 l'Université Polytechnique de la Catalogne (UPC) entrepris l'utilisation d'un outil d'enseignement virtuel, le campus virtuel Atenea. Depuis 2005 Atenea est basé sur Moodle, une plate-forme d'apprentissage en ligne sous licence *open source* avec un système de gestion de contenu, qui permet aux enseignants de construire des cours en ligne –tout en assurant leur qualité– et de gérer les résultats de l'apprentissage. Parmi les outils ajoutés par Moodle, notre intérêt est centré essentiellement sur le module Test. Ce module permet la création de tests composés de questions de types différents, adaptés aux buts spécifiques à atteindre dans chaque étage du processus d'enseignement-apprentissage. Le module Test peut aider à l'intégration des nouvelles stratégies pédagogiques, autrement impossibles à implanter avec les outils traditionnels. Afin d'examiner comment ces nouvelles stratégies peuvent être employées à travers la création d'une banque substantielle de questions, nous sommes en train d'exécuter des projets financés par l'Institut de Sciences de l'Éducation de l'UPC. Cette communication est basée sur l'évaluation de trois tests Moodle concernant le sujet Calcul et répondus par environ 70 étudiants de première année de l'École des Ponts et Chaussées (UPC) pendant le cours 2007/2008. Nos buts sont d'un côté, analyser les réponses des étudiants, et de l'autre, exécuter une analyse psychométrique pour identifier si les questions proposées sont proprement effectifs.

1. Introduction

It goes without saying that the introduction of e-learning and information and communication technologies provides a new, but rather complex, framework for mathematical education. There are many ideas, items and experiences to present and discuss, such as how the new technologies can help in the design of mathematical activities, and what kind of topics have emerged from the existence of these new technologies. It is essential to know how to put new activities into practice, as well as how to improve them through the assessment of their implementation. The European Higher Education Area (EHEA) promotes a student-centered system based on the student workload required to achieve the objectives of a study program. These objectives should preferably be specified in terms of the learning outcome to be acquired. Learning outcomes are sets of competences, a dynamic combination of attributes, abilities and attitudes, expressing what the student will know, understand or be able to do after completion of a process of learning. Hence, in the context of EHEA, e-learning tools provide an outstanding opportunity to discuss the mathematical activity in the 21st-century classroom.

In 2002 the Technical University of Catalonia (UPC) undertook the use of a virtual teaching tool, the virtual campus Atenea, as a first step towards the EHEA. Since 2005 Atenea is based on Moodle, an open source learning management system designed to help educators create quality online courses and administer learner

outcomes. From the wide range of tools offered by Moodle, we are focusing on the quiz module. This module allows the creation of quizzes with different question types, adapted to the specific objectives to be achieved at any step in the teaching-learning process. A powerful tool for monitoring and diagnosing a student's understanding, Moodle quizzes contribute to the development of new strategies not feasible with paper-and-pencil exams. To explore how to apply these new strategies in the development of a substantial bank of quiz questions, we are carrying out projects subsidised by the Institute of Education Sciences of the UPC. We intend to design effective questions to supervise students' progress at each level of the learning process, articulated in specified learning outcomes and skills: knowledge, comprehension, application, analysis and problem solving. In this contribution we outline a preliminary experience regarding the use of the quiz module for Calculus topics which constitute primarily the core of a compulsory undergraduate course developed at the School of Civil Engineering (UPC). The development of teaching materials involving Calculus had already been attempted as early as 2003 within the framework of Moodle. Once implemented on Atenea, these materials proved suitable for independent and private study, plus self-assessment, in agreement with EHEA guidelines [1-4]. To the purpose of this contribution, in the course 2007/2008 three Moodle quizzes were designed to be answered by around 70 first-year students of the School of Civil Engineering. In the design of each of the questions, we took into account the following points: i) Why is this an interesting question? ii) What skill or procedure is being assessed here? iii) What answers do we expect? iv) What obstacle could there be when answering this question?

As it is an interactive and dynamic tool, we believe that Moodle quizzes will serve to boost effectiveness and promote student performance, as well as change teachers' and students' attitude towards the virtual campus Atenea. Besides, the automatic assessment of the quizzes frees up time for the teacher to concentrate on other aspects of the learning process. However, it is essential to bear in mind that the whole process should be permanently revised and updated. In this sense it was worth carrying out an assessment of the first experiences in the Calculus course mentioned above, since it provided insights into the entire process. This contribution focuses on the assessment of the three Moodle quizzes for Calculus topics. In particular, the aims are to analyse students' answers on the one hand, and to carry out a psychometric analysis to identify the appropriateness of the questions stated in the quizzes on the other. From this first experience, we intend to generate improved quizzes suitable for the compulsory undergraduate subjects in the applied mathematics field, which are included in the first and second year syllabus for all branches of Engineering.

2. Design of Moodle quizzes for the evaluation of Calculus topics

In the context of this work, students' progress is assessed by a weighted combination of two written pencil-paper exams during the course (Exam1 and Exam2), a final summative written examination (FinalExam) and several coursework assignments. If the mean of Exam1 and Exam2 does not exceed the pass mark, students have to take the final exam at the end of the course. This being a first experience in the field, we did not consider it convenient to confer an essential weight to the three Moodle quizzes. Therefore, they were regarded as plain coursework assignments to be carried out in the classroom. The quiz dates were: Test 1 in October 2007; Test 2 November 2007; Test 3 March 2008. The three quizzes consisted of ten multiple-choice questions, offering in this case only weaker feedback, that is, students were given only the knowledge of their own score or grade, often described as "knowledge of results," without the knowledge of correct results, nor any additional explanation or suggestions for improvement. The topics covered by Test 1 were complex and real numbers, and topology. Test 2 covered mainly limits and series, while Test 3 focused on geometry in R^3 and multivariable functions. The mathematical tasks may be classified in different requested levels of mastery of knowledge. MATH taxonomy (Mathematical Assessment Task Hierarchy) for the structuring of assessment tasks [6] turns out to be more appropriate for mathematical tasks than Bloom's taxonomy. We agree with Smith [6] in that "the aim of the descriptors is to assist with writing examination questions, and to allow the examiner's judgment, objectives and experience to determine the final evaluation of an assessment task". The MATH taxonomy uses eight different descriptors that are shown in Table 1, along with some illustrative questions used in these tests.

Table 1. Examples of classification according to the MATH taxonomy.

Factual knowledge	5_Test 1.- Which statement is true?: a) Every numerable set is finite. b) Every subset of a numerable set is numerable. c) R is numerable. (d) N is not numerable.
Comprehension (recognition of formulas and situations)	1_Test 3.- The surface given by $2x^2 + 3y^2 = 1$ is: (a) an elliptic cylinder b) an elliptic cone (c) an ellipse (d) a hyperboloid of one sheet (e) none of the above.
Routine use of procedure or algorithms	1_Test 1.- The value of the expression $i^{101} + i^{-207}$ is: (a) $1+i$ (b) $1/i$ (c) $-2i$ (d) $2i$ (e) None of the above.
Information transfer (classification of math objects)	6_Test 1.- Considering the sets of real number R, of rational numbers Q and of the irrational numbers I, then: (a) All the statements are true. (b) $\forall x \in \mathbb{R} \Rightarrow \exists n_0 \in \mathbb{N}$ such that $n_0 > x$ (c) $\forall x, y \in \mathbb{R}, x < y \Rightarrow \exists p\sqrt{2} \in \mathbb{I}$ with $p \in \mathbb{Q}$ such that $x < p\sqrt{2} < y$ (d) $\overline{\mathbb{Q} \cap (0,1)} = [0,1]$
Application in new situations (planning work, selection of methods)	5_Test 3.- The spheres $x^2 + y^2 + z^2 - 4$, $(x-1)^2 + y^2 + z^2 - 1$ (a) do not intersect (b) are tangent at the point $(0,0,2)$ (c) are tangent at the point $(2,0,0)$ (d) are perpendicular at the point $(2,0,0)$ (e) None of the above.
Justifying, proof, reasoning and interpreting	8_Test 3.- The expression $x \frac{\partial f}{\partial x} + y \frac{\partial f}{\partial y} = 1$ in polar coordinates is: (a) $\frac{\partial f}{\partial r} = \frac{1}{r}$ (b) $r \frac{\partial f}{\partial r} = \frac{1}{r}$ (c) $\frac{\partial f}{\partial \theta} = \frac{1}{r^2 \cos(\theta) \sin(\theta)}$ (d) $r \frac{\partial f}{\partial r} + 2r^2 \cos(\theta) \sin(\theta) \frac{\partial f}{\partial \theta} = 1$ (e) None of the above.
Implications, making conjectures, comparisons and finding patterns	9_Test 1.- In Euclidean space (R,d) for any $x, y, z \in \mathbb{R}$ the inequality $ x + y \leq x + z + z - y $ (a) only holds if $ z \leq y $ or $ z \leq x $ (b) only holds if $z=x=y$ (c) always holds (d) never holds.
Evaluation	6_Test 2.- Decide which is the only true statement: (a) $\lim_{n \rightarrow \infty} \sqrt[n]{n^2 + 1} = 1$ (b) $\lim_{n \rightarrow \infty} \left(1 - \frac{2}{n+3}\right)^n = e^2$ (c) $\lim_{n \rightarrow \infty} \sqrt[n]{n} = 0$ (d) $\lim_{n \rightarrow \infty} \left(\frac{n+3}{n-1}\right)^n = e^2$ (e) None of the above.

3. Results and discussion

Given the novelty of the technological tools and the pedagogical approach involved, an analysis of students' results and a psychometric analysis are essential in this kind of assessment [5], all the more so because, the quizzes covered an important part of the syllabus of a Calculus course for undergraduate engineers. The three tests have the same form for all students in this group, so a straightforward statistical analysis is possible.

3.1. Analysis of students' results

The descriptive summary in Table 2 shows that the first quiz is the best scored and that the second test bears the highest coefficient of variation. Remarkably enough, the third quiz was the one taken by the lowest number of students. The overall scores of the students in the three tests are displayed in Figure 1.

Table 2. Descriptive analyses of the scores of the quizzes. N: Number of examinees; N*: Number of non-examinees; SE: Standard Deviation of the Mean; CV: Coefficient of Variation; Q1: Percentile 25%; Q3: Percentile 75%.

	N	N*	Mean	SE	CV (%)	Q1	Median	Q3	% of pass
Test 1	66	8	5,50	0,22	31,7	4,0	6,0	7,0	72,7
Test 2	73	1	4,14	0,26	53,3	3,0	4,0	5,5	41,1
Test 3	61	13	4,30	0,21	37,9	3,0	4,0	5,0	42,6

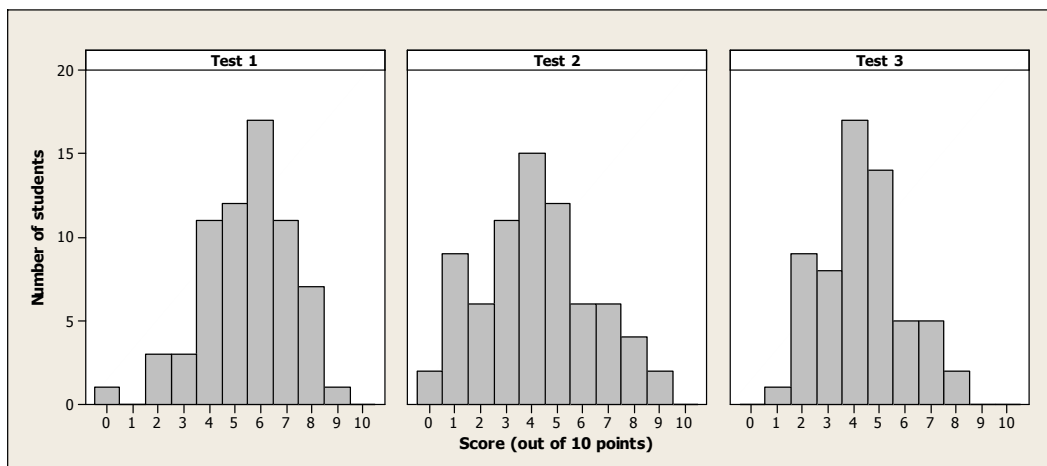


Figure 1. Histogram of students' scores in the three tests.

We performed a regression analysis relating the score mean of the three quizzes to the marks of the three written exams. Should the analysis display good correlation, they would render Moodle quizzes a convenient tool to inform students of their performance throughout the learning process. Figure 2 shows that correlation between the mean of the three quizzes and Exams 1 and 2 is positive ($r = 0.483$ and 0.499 , respectively) and greater than the one corresponding to the final written exam ($r = 0.161$). For both Exam1 and Exam2, linear regression is significant (with p-values 0.001 and 0.008, respectively), while the model concerning the final written exam is not significant (p-value=0.339). This can be explained by the fact that those students who took the final exam were the bad performers.

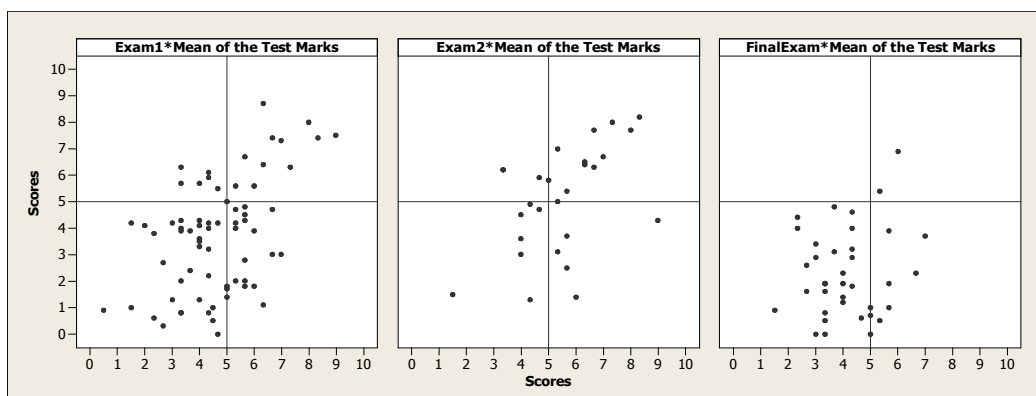


Figure 2. Scatter diagrams of students' scores in the three tests (mean) versus Exams 1, 2 and final scores (sample sizes 70, 27 and 37, respectively).

3.2. Psychometric analysis

In this section we analyze the psychometric quality of the assessments, which can help us to answer whether there are appropriate questions, well chosen to demonstrate concepts and of an appropriate level of difficulty and whether the questions discriminate between higher and lower mathematical abilities. Again Moodle offers a range of resources to carry out a psychometric analysis of a particular quiz, namely the Facility Index (FI), the Discrimination Index (DI) and the Discrimination Coefficient (DC). Item FI describes the overall difficulty of the questions. This index represents the ratio of users that answer the question correctly. In principle, a very high or low FI suggests that the question is not useful as an instrument of measurement. There are two descriptors to measure effectiveness, DI and DC, both ranging from -1 to +1. The DI provides a rough indicator of the performance of each item to separate high scores vs. scorers. The DC is a correlation coefficient between scores at the item and at the whole quiz. In both cases, positive values indicate items that discriminate proficient learners, whereas negative indices mark items that are answered best by those with lowest grades, hence not helping to discern between the good and the bad performers. In short, these coefficients can be used as powerful methods of evaluating the effectiveness of the quiz when assessing

differentiation of learners. The advantage of using DC over DI is that the former uses information from the whole population of learners, and not just the extreme upper and lower thirds. Thus, this parameter may be more sensitive to detect item performance.

Let us summarise briefly the psychometric analysis for the three quizzes involved in this contribution. FI for ranges from 27% to 88% for Test 1; from 16% to 66% for Test 2; and from 3% to 70% for Test 3. By and large, most of the questions in Test 1 show high values for DI, yet lower values for DC. On the contrary, DI turns out to be rather low in most of the questions of Tests 2 and 3. For instance, question **9_Test1**, with a FI of 70%, displays a high DI (0.889) and medium DC (0.464); **6_Test2**, with a FI of 59%, shows a low DI (0.107) and a low DC (0.377); **8_Test3** bears really low values for FI (13%), DI (0.056) and DC (0.256) (see Table 1 to check the statements).

4. Final remarks

As mentioned above, this paper gathers the results of a preliminary study. To construct more suitable quizzes in the future, our intention is to carry out an analysis of some computational or algebraic mistakes, and other common misconceptions, using the total results given by the psychometric analysis. We are also planning to add a wider variety of questions and to include further feedback facilities.

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