CREATING MOODLE QUIZZES FOR THE SUBJECTS OF MATHEMATICS AND STATISTICS CORRESPONDING TO THE FIRST YEARS IN ENGINEERING STUDIES

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Abstract

In 2005 the virtual campus Atenea of the Technical University of Catalonia (UPC) started to use Moodle, an open source learning management system that offers a wide variety of teaching tools [3]. One of these tools, the quiz module, represents an alternative to traditional face-to-face courses and paper-based testing. In order to explore how to apply this new strategy, in 2008 we started to carry out a project subsidised by the Institute of Education Sciences (ICE) of the UPC. The project title was "Creating Moodle quizzes for the subjects of Mathematics and Statistics corresponding to the first years in engineering studies". It covered the compulsory undergraduate subjects in applied mathematics included in the first- and second-year syllabus for all branches of Engineering. The aims were to elaborate a substantial range of Moodle question pools and to design, implement and assess a series of quizzes, to use Moodle quizzes to promote more effective, dynamic and autonomous learning, and to change teachers' and students' attitude towards the campus Atenea.

Keywords - Moodle quizzes, applied mathematics, engineering studies.

1 INTRODUCTION

In 2005 the virtual campus Atenea of the Technical University of Catalonia (UPC) started to use Moodle, an open source learning management system that offers a wide variety of teaching tools. One of these tools, the quiz module, represents an alternative to traditional face-to-face courses and paper-based testing. In order to explore how to apply this new strategy, in 2008 we started to carry out a project subsidised by the Institute of Education Sciences (ICE) of the UPC. The project title was "Creating Moodle quizzes for the subjects of Mathematics and Statistics corresponding to the first years in engineering studies". It covers the compulsory undergraduate subjects in applied mathematics included in the first- and second-year syllabus for all branches of Engineering [2]. This contribution aims to show how this project progressed. The goals of the project were:

1) To elaborate a substantial range of Moodle question pools and to design, implement and assess a series of quizzes.
2) To use Moodle quizzes to promote more effective, dynamic and autonomous learning.
3) To change teachers' and students' attitude towards the campus Atenea, stressing its interactive role in the teaching-learning process, far beyond its role as static course material manager.

The question pools covered the mathematical and statistical topics taught at the School of Agricultural Engineering of Barcelona (ESAB) in Spain [http://www.esab.upc.edu]. So far agricultural engineering studies are divided into six semesters, comprising an industrial training period and a final degree project. The ESAB offers three programmes leading to the following diplomas: Crop and Livestock Management, Horticulture and Gardening Studies and Agri-Business Management and Food Marketing. The compulsory subjects in the field of mathematics taught at this School are Mathematics 1, Mathematics 2 and Statistics. The subjects object of this contribution are Mathematics 1 and Mathematics 2. Mathematics1 is taught in the first semester (60 lecturing hours), covering the topics of Algebra and Differential Calculus. Mathematics 2 is taught in the second semester (45 lecturing hours), covering the topics of Integral Calculus and Ordinary Differential Equations (ODEs). It is worth mentioning that those students who do not pass all the mandatory first-year subjects (Mathematics 1 and 2 are here included) are not allowed to register for subjects in second and third years. What is more, they may not be able to continue their studies at the School. This proves to be a source of pressure, for students focus their interest and work on those subjects, which they feel they can manage to pass with a reasonable amount of effort. In the mathematics we teach at the School, the teaching and learning process is accomplished through a mixture of lectures, problems classes and computer lab sessions. Students' progress is assessed by a weighted combination of one written examination during the semester (Exam 1), a written summative examination (Exam 2), and several coursework assignments. The latter comprise class-work, assessed homework and computer practicals. As far as the diplomas Crop and Livestock Management and Horticulture and Gardening Studies are concerned, the assessment in Mathematics 1 and 2 is achieved by using the following weighted formula: Exam 1 (25%), Exam 2 (50%) and computer practicals plus coursework (25%).

2 DESIGN OF MOODLE QUIZZES FOR THE ASSESSMENT OF MATHEMATICS 1 AND MATHEMATICS 2

To start with we analysed how to develop effective question-design strategies to supervise students' progress at different stages of the learning process [6]. For instance, concerning Mathematics 1 and Mathematics 2 we created quizzes for different contexts, such as diagnostic and post-performance tests, in computer lab sessions, and for chapter checking after the accomplishment of each unit of content. This contribution focuses on the set of Moodle quizzes that were designed to be worked out in computer lab sessions. In the context of Mathematics 1, computer lab sessions were organised in two-hour sessions, every other week (both Crop and Livestock Management and Horticulture and Gardening Studies together). As for Mathematics 2, in the diploma of Crop and Livestock Management they were organised in one-hour sessions, weekly (group A), whereas in Horticulture and Gardening Studies the pattern was again two-hour sessions, every other week (group H). We designed six quizzes for Mathematics 1 and eight for Mathematics 2. Quiz questions can be of different types: multiple-choice questions, true/false, short-answer questions, numerical questions, matching questions, calculated questions and embedded answer questions. Table 1 shows the number of questions used in the quizzes implemented in Mathematics 1 (M1) and Mathematics 2 (M2), grouped by question type. Tables 2 and 3 display the topics covered by each quiz in Mathematics 1 and Mathematics 2, respectively.

Table 1. Number of questions and question types

	Num. of questions	Multiple-choice	True/false	Matching questions	Short-answer/numerical
M1	58	31	11	7	9
M 2	59	15	44		

Table 2. Topics covered by quizzes in Mathematics 1

M1	Q1	Q2	Q3	Q4	Q5	Q6
	Matrixes	Determinants	Systems of linear equations	Discussion of systems of linear equations for parameters	Complex numbers	Trigonometry, complex numbers, plane geometry, real functions

Table 3. Topics covered by quizzes in Mathematics 2

M2	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
	Basic integration by substitution		Integration by substitution	Integration by parts	Integration by partial fractions	ODEs: general topics	Separable ODEs	Homogeneous ODEs

Before implementing the quizzes, we examined the options of the quiz module. One of the attractive options is that teachers can decide whether to show feedback after answering. Since assessment is one of the most important activities in education, feedback on performance plays a relevant role in the teaching-learning process. Getting quick feedback after a quiz is a useful tool for students to evaluate their own activity and helps them become more successful, since they can analyse their own way of thinking and begin to understand why an answer is not correct. Besides, involving frequent, low-stakes assessments during the course provides a very flexible system for evaluating student achievement, keeps students engaged in the class, and may reduce the rate of anxiety before infrequent, high-stakes tests. Our preference here was to allow students to go over their grade, their responses and the correct answers once the quizzes were accomplished.

3 ANALYSIS OF RESULTS

In the context of our project, the quiz module provided information of which questions our students got wrong or partially right, overall quiz results, individual responses, and attempt summaries. It was also a great tool for assessing whether the questions were suitable to discriminate between good and bad performers. All the statistical reports were downloaded as an Excel file, rendering all the information easier to manage.

3.1 Analysis of students' results

The descriptive summary in Table 4 shows that the first quiz is the best scored and that the third test bears the highest coefficient of variation. Remarkably enough, all the students passed the first and fourth quizzes. When it comes to Mathematics 2, the general descriptive summary is gathered in Table 5. This time, the sixth test was the best scored and the seventh shew the highest coefficient of variation. All students passed the fifth and sixth quizzes. The descriptive summaries of groups A and H regarded separately (Table 6) reveal only slight differences in means, except in the seventh quiz, where the difference seems to be rather notable. Since we were interested in tracing individual improvement, from the numerical marks got by those students who took both the quizzes and Exam 1 the scatter plots in Fig. 1 and Fig. 2 were obtained. We performed the plots relating the score mean of the quizzes to the marks of the written exam (Exam 1). Should the analysis display good correlation, they would render Moodle quizzes a convenient tool to inform students of their performance throughout the learning process. Unfortunately, the fact that all the points lay in the first and fourth quadrant seem to indicate a non-positive correlation (high scores in the quizzes, low scores in Exam 1). However, in Fig. 1 it can be observed a higher concentration of points in the first quadrant. When it comes to Mathematics 2 (Fig. 2), it is true that group A is mainly concentrated on the fourth quadrant. And the same applies for half of group H, whereas the other half is located in the first quadrant, hence pointing to a better correlation.

Table 4. Mathematics 1: 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%

TEST_M1	N	N*	Mean	SE	CV(%)	Q1	Median	Q3	% of pass
Q1	31	11	9.4	0.16	9.5	8.7	10.0	10.0	100
Q2	31	11	7.9	0.28	19.8	7.5	7.8	8.7	93
Q3	33	9	7.4	0.42	32.7	5.0	8.0	9.5	85
Q4	32	10	8.2	0.28	19.4	7.0	8.5	10.0	100
Q5	32	10	8.7	0.27	17.6	8.0	9.2	10.0	97
Q6	30	12	8.5	0.27	17.8	8.0	8.7	9.3	93

Table 5. Mathematics 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%

TEST_M2	N	N*	Mean	SE	CV(%)	Q1	Median	Q3	% of pass
Q1	30	4	8.0	0.29	19.9	7.0	8.0	9.3	97
Q2	30	4	6.8	0.31	24.8	6.0	7.0	8.0	87
Q3	31	3	8.2	0.35	24.0	7.1	8.6	10.0	90
Q4	30	4	8.2	0.33	21.9	6.7	8.3	10.0	97
Q5	29	5	8.9	0.27	16.5	8.0	10.0	10.0	100
Q6	31	3	9.0	0.22	13.5	8.0	9.0	10.0	100
Q7	27	7	6.5	0.54	43.5	5.0	6.0	10.0	78
Q8	24	10	7.7	0.45	28.4	6.0	8.0	10.0	84

Table 6. Mathematics 2: Descriptive analyses of the scores of the quizzes grouped by diploma (A, H). 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%

TEST_M2	Group	N	N*	Mean	SE	CV(%)	Q1	Median	Q3
Q1	A	11	1	7.6	0.45	19.7	7.0	8.0	8.0
	H	19	3	8.2	0.38	20.1	7.0	9.0	10.0
Q2	A	11	1	6.7	0.38	18.9	6.0	7.0	8.0
	H	19	3	6.8	0.44	28.1	6.0	7.0	8.0
Q3	A	12	0	7.7	0.65	28.9	7.1	8.6	9.6
	H	19	3	8.6	0.41	20.8	7.1	8.6	10.0
Q4	A	11	1	8.0	0.59	24.2	6.7	8.3	10.0
	H	19	3	8.3	0.40	21.1	6.7	8.3	10.0
Q5	A	11	1	8.5	0.47	18.4	8.0	8.0	10.0
	H	18	4	9.1	0.33	15.5	8.0	10.0	10.0
Q6	A	12	0	8.7	0.43	17.3	8.0	9.0	10.0
	H	19	3	9.2	0.22	10.6	8.0	10.0	10.0
Q7	A	11	1	4.6	0.72	51.3	2.0	5.0	6.0
	H	16	6	7.7	0.60	31.1	5.3	8.5	10.0
Q8	A	11	1	7.8	0.74	31.2	6.0	8.0	10.0
	H	13	9	7.5	0.56	26.9	6.0	8.0	9.0

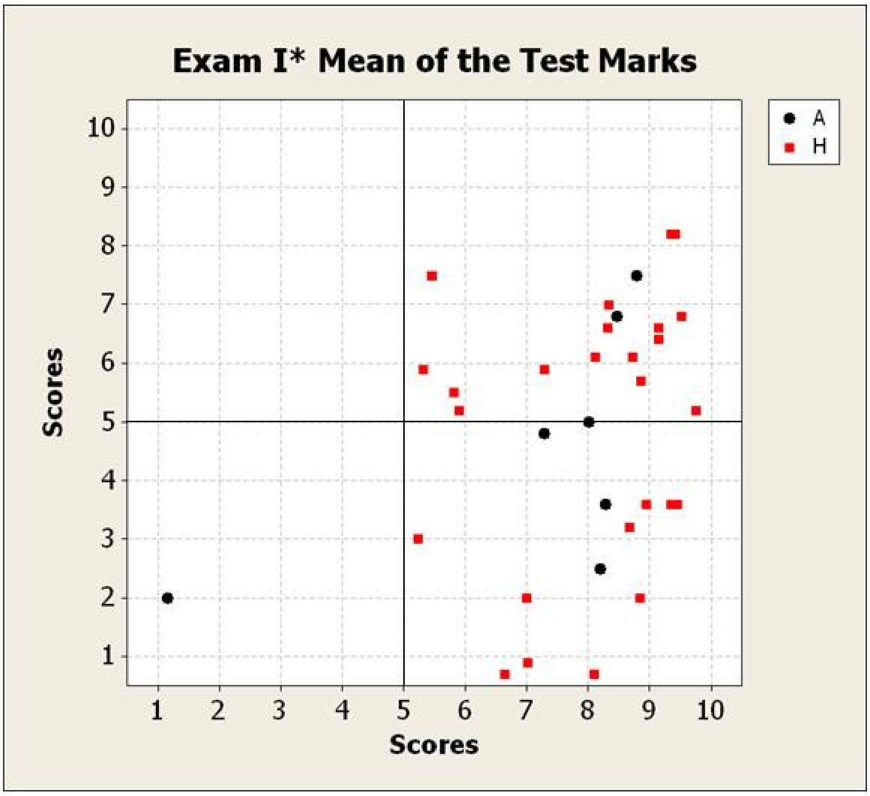

Figure 1. Mathematics 1: Scatter plots of students' scores in the six tests (mean) versus Exam 1 scores (sample size 33, of which A: 7 and H: 26)

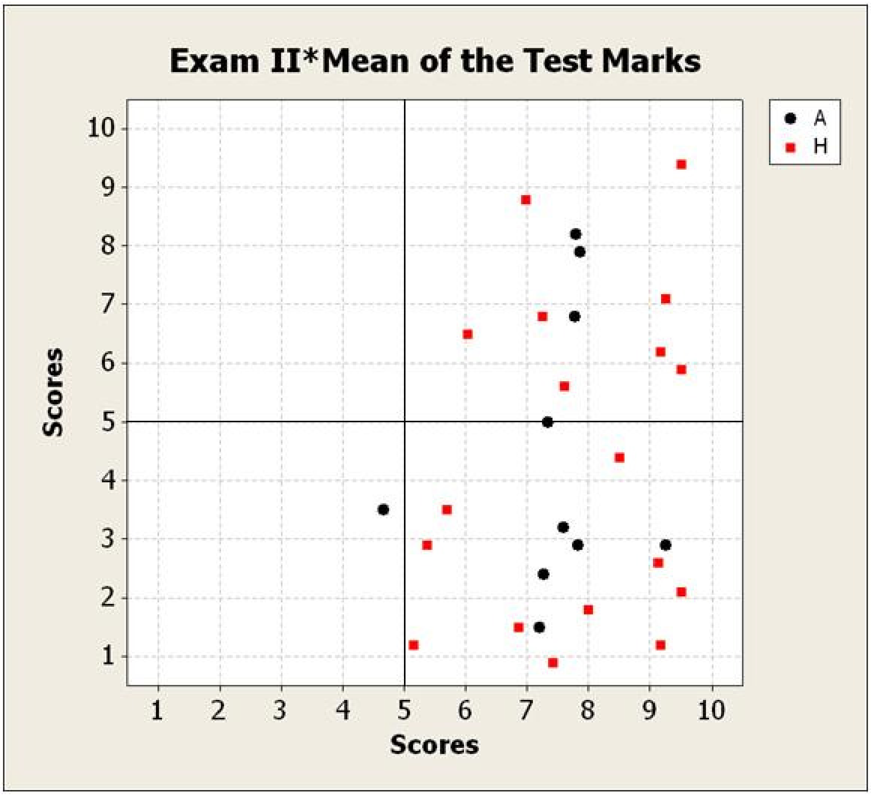

Figure 2. Mathematics 2: Scatter plots of students' scores in the six tests (mean) versus Exam 1 scores, grouped by diploma (sample sizes A: 11 and H: 19)

Furthermore, these tests contributed to control the index of absenteeism. Regarding Mathematics 1, the 33 students who took the quizzes took also Exam 1. As for Mathematics 2, of the 31 students who performed the quizzes, 30 students took Exam 1 (one student took Exam 1 without having performed the quizzes). Therefore, we can conclude that most of the students who performed the quizzes, subsequently took Exam 1. Compared with previous semesters, this is quite a negligible ratio of absenteeism [1].

3.2 Psychometric analysis

In this section we analyse 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 [4]. 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). The index 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. This is a measure of how easy or difficult is a question for quiz-takers. It is calculated as: FI = $(X_{average}) / X_{max}$ where $X_{average}$ is the mean credit obtained by all users attempting the item, and X_{max} is the maximum credit achievable for that item. 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, proficient *vs.* less-proficient users. This parameter is calculated by first dividing learners into thirds based on the overall score in the quiz. Then the average score at the analysed item is calculated for the groups of top and bottom performers, and the average scored substracted. The matematical expression is: DI = $(X_{top} - X_{bottom})/ N$ where X_{top} is the sum of the fractional credit (achieved/maximum) obtained at this item by the 1/3 of users having the highest grades in the whole quiz (i.e. number of correct responses in this group), and X_{bottom}) is the analog sum for users with the lower 1/3 grades for the whole quiz. The DC is a correlation coefficient between scores at the item and at the whole quiz. This is another measure of the separating power of the item to distinguish proficient from weak learners. It is calculated as: DC = $Sum(xy)/ (N * s_x * s_y)$ where Sum(xy) is the sum of the products of deviations for item scores and overall quiz scores, N is the number of responses given to this questions_x is the standard deviation of fractional scores for this question and, s_y is the standard deviation of scores at the quiz as a whole. 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. That is to say, values below 0.0 mean that more of the weaker learners got the item right than the stronger learners. Such items should be discarded as worthless. In fact, they reduce the accuracy of the overall score for the quiz. 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 [5].

In this contribution, we are focusing on the analysis of FI and DC. Table 7 summarises briefly the psychometric analysis for the six quizzes performed in Mathematics 1. Since there were two groups involved (A, H) in the eight quizzes run in Mathematics 2, Tables 8 and 9 display their psychometric summary separately. Concerning the FI, the tables below show the range of values and the percentage of questions with values between 15 and 85 for each quiz (to discard too low and too high values). As for the DC, values are classed into three categories: Low (DC $\leq$ 0.33), Medium, High (DC $\geq$ 0.66). For each quiz the tables below present the percentage of questions in each of these categories. Those quizzes with just few questions with FI values between 15 and 85 should be newly constructed, as well as those with low values of DC. For instance, regarding Mathematics 1, FI ranges from 90% to 100% for Q1, whereas it ranges from 59% to 82% for Q3 (see Table 7). The high values for FI in Q1 are in keeping with the fact that half of the questions show low values for DC. On the contrary, Q3 shows no questions with low DC. When it comes to the quizzes performed in Mathematics 2, the analysis of psychometric quality turns out to be rather difficult. The fact that there were two groups who performed the quizzes in different contexts certainly hindered the overall analysis. Hence, while 60% of the questions in Q6 (group A) show values of FI between 15 and 85, only 20% of the questions in Q6 (group H) are included in this range. 33% of the questions of Q7 (group A) with low values for DC, no question in the same quiz performed by group H (see Tables 8 and 9 to check the statements). For next year, we set ourselves the goal to revise not only those quizzes with low values for DC or too low/ too high values for FI, but also those with different values for the same coefficients for groups A and H.

Table 7. Mathematics 1: Psychometric analysis of the six quizzes.

M1	%FI		DC		
	Range	(15,85)	% Low	% Medium	% High
Q1	90-100	0	50	33	17
Q2	50-94	75	-	88	12
Q3	59-82	100	-	55	45
Q4	63-97	33	33	50	17
Q5	69-97	40	20	60	20
Q6	53-100	33	40	40	20

Table 8. Mathematics 2 (group A): Psychometric analysis of the eight quizzes.

M2 - A	%FI		DC		
	Range	(15,85)	% Low	% Medium	% High
Q1	45-91	60	70	30	-
Q2	18-100	80	50	50	-
Q3	58-92	57	29	57	14
Q4	55-100	66	50	33	17
Q5	45-100	20	40	40	20
Q6	58-100	60	40	40	20
Q7	9-73	83	33	33	33
Q8	55-100	60	20	40	40

Table 9. Mathematics 2 (group H): Psychometric analysis of the eight quizzes.

M2 - H	%FI		DC		
	Range	(15,85)	% Low	% Medium	% High
Q1	68-100	80	40	40	20
Q2	32-89	90	20	70	10
Q3	68-95	57	29	29	42
Q4	68-95	66	33	33	33
Q5	78-100	20	40	40	20

Q6	74-100	20	60	40	-
Q7	56-83	100	-	33	67
Q8	38-92	60	40	20	40

4 Analysis of student ratings of Moodle quizzes

The improvement of one's own teaching relies largely upon the knowledge of how a class goes and where changes may be needed or attempted. By the end of the semester our students usually rate the importance of items regarding learning, satisfaction, course characteristics, assignments and workload. This year they were also invited to comment on the development of the quizzes they performed in computer lab sessions during the course. Though not the only source of feedback, student ratings provide an excellent guide for designing the teaching process and, in particular, for assessing their motivation. Therefore, at the end of the activity students were asked to rate the quizzes used in computer lab sessions by answering the following items:

I1. Relative to other courses, the workload for computer lab sessions this course was
(1) Very heavy (2) Heavy (3) Reasonable (4) Light (5) Very light

I2. Have you used Moodle before taking this course?
(1) Not at all (2) Seldom (3) Sometimes (4) Often (5) Always

I3. In my opinion, the pace at which the quizzes were presented was (relative to lectures)
(1) Too fast (2) Fast (3) About right (4) Slow (5) Too slow

I4. Overall, I would rate the quizzes performed in computer lab sessions as
(1) Very poor (2) Poor (3) Satisfactory (4) Good (5) Very good

I5. The quizzes helped me to understand some of the topics covered in the theoretical classes.
(1) Strongly disagree (2) Disagree (3) Neutral (4) Agree (5) Strongly agree

I6. Once answered, I got enough information about correct answers.
(1) Strongly disagree (2) Disagree (3) Neutral (4) Agree (5) Strongly agree

I7. Performing the quizzes has made me more interested in the subject
(1) Strongly disagree (2) Disagree (3) Neutral (4) Agree (5) Strongly agree

I8. I think my scores on quizzes were fair.
(1) Strongly disagree (2) Disagree (3) Neutral (4) Agree (5) Strongly agree

I9. What positive aspects regarding the quizzes could you write down?
I10. What improvements to the quizzes could you suggest?

Figures 3 and 4 show the results of this survey. Relative to other courses, 79% and 52% of the students considered the workload for Mathematics 1 and Mathematics 2, respectively, to be reasonable (I1). Most of the students had never, or only seldom, used Moodle before taking this course (I2). According to 66% of the students of Mathematics 1 and 52% of Mathematics 2, the pace at which the quizzes were presented was about right (I3). Of the students of Mathematics 1 and Mathematics 2 who performed the quizzes, 95% and 81% of them, respectively, regarded the activity positively (I4). According to 84% of the students of Mathematics 1 and 67% of Mathematics 2, the quizzes helped them to understand some of the topics covered in lectures (I5). Information provided once the quizzes were answered was not as well rated as the items already discussed (I6). Actually this rating matches with some of the negative aspects mentioned by students in I10, discussed below. When it comes to I7, 55% of the students of Mathematics 1 agreed, or strongly agreed, whereas this ratio was only 37% in Mathematics 2. Finally, while 74% of the students of Mathematics 1 agreed, or strongly agreed, with their scores on quizzes, only 55% of the students in Mathematics 2 rated their scores as fair. In short, our overall impression is that students of Mathematics 1 regarded the quizzes performed more positively than students of Mathematics 2. The nature of the contents of Mathematics 1 might be more suitable for this kind of activity than Mathematics 2, hence explaining this preference.
We single out the following additional comments concerning item I9: “It is an easy way to put into practice the theoretical concepts learnt in class”, “Entertaining”, “They allow you to discuss your concerns with your teachers and classmates”, “Quick assessment”, “They offer you the opportunity to work in class”. Relative to item I10, we highlight the following “negative aspects”: “The time available to perform a quiz is insufficient”, “Too quick and weighty for a two-hour session every two weeks”.

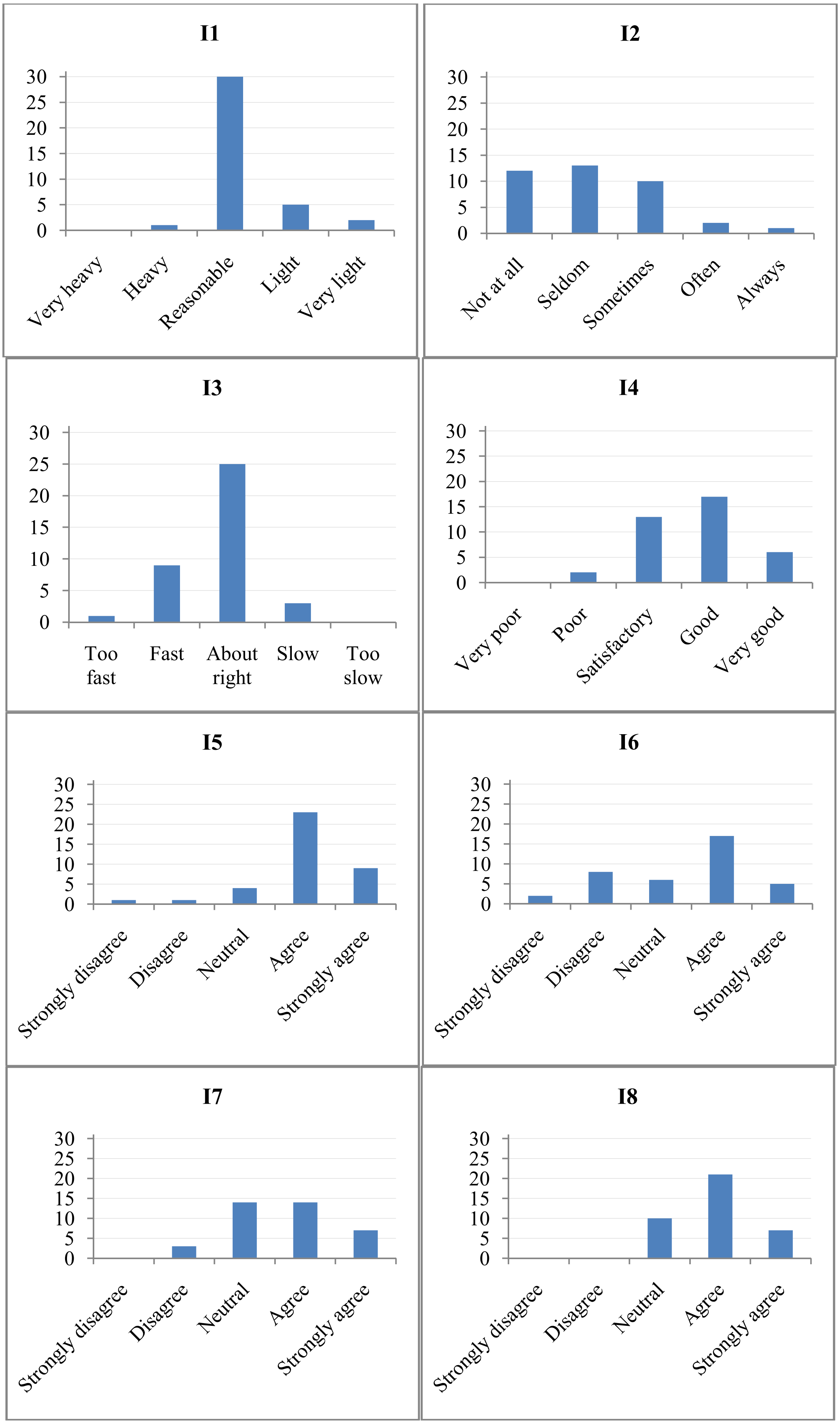

Figure 3. Mathematics 1: Student ratings

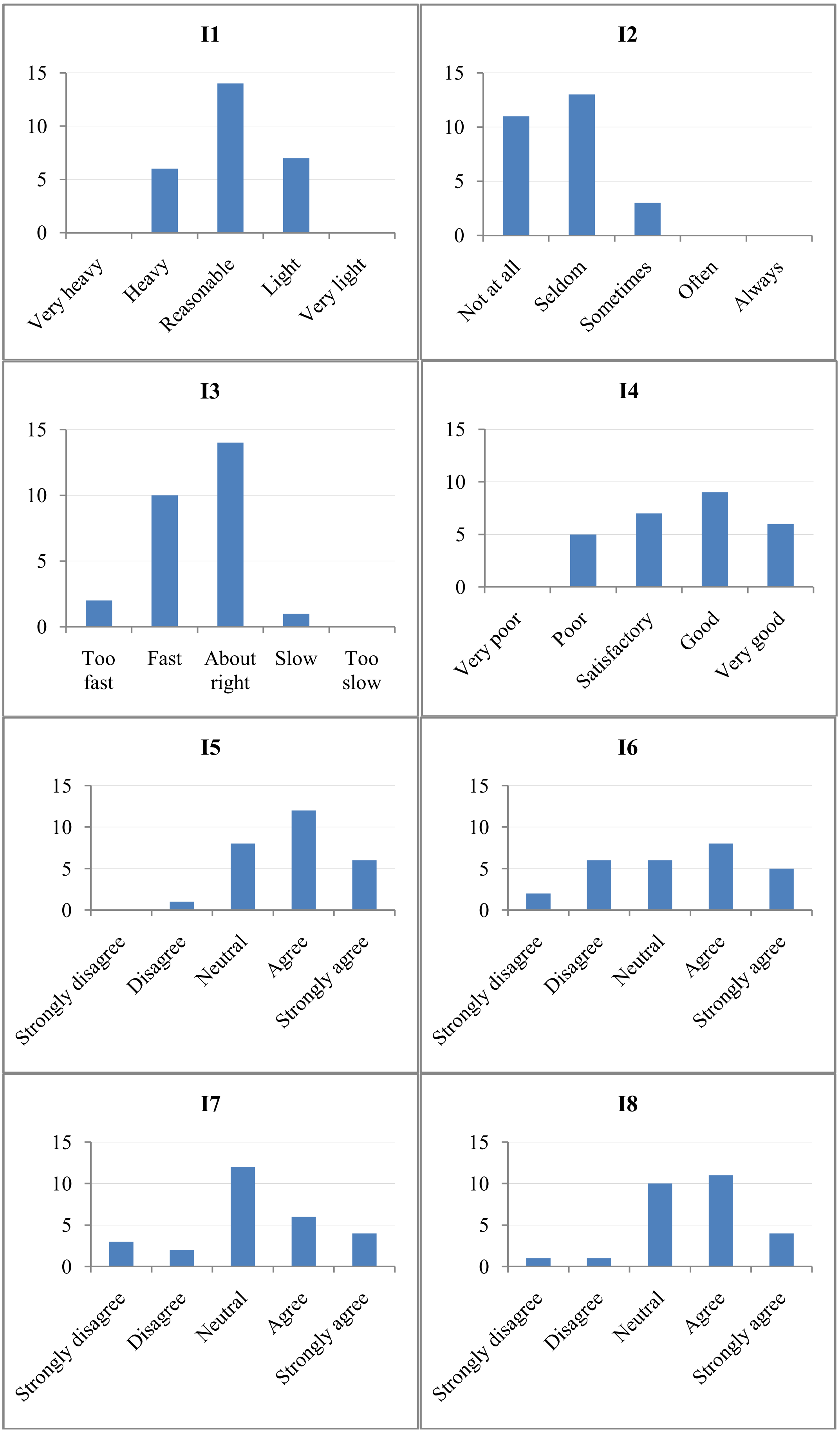

Figure 4. Mathematics 2: Student ratings

5 Final remarks

From this preliminary experience, we can conclude that Moodle quizzes are certainly useful to promote student involvement in the subject. To help boost effectiveness in the learning process, our intention is to design anew some of the quizzes in the future, taking into account the total results given by the psychometric analysis. We are also planning to add a wider variety of questions (including cloze and calculating questions) and to explore further feedback facilities.

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