Linking Assessment to e-Learning in Microbiology and Toxicology for Undergraduate Students

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Development of communication and information technology opens the possibility to create new learning and assessments tools. Beyond the world wide access to education across the country and globe, the opportunity of running virtual experiments and assisting processes modelling, the communication and information technology facilitate implementation of collaborative learning, promoting active implication of students in educational process. Regarding the assessment process, its design had also been changed, the concept of computer-aided assessment being more frequently used at university and post-university level. The students' knowledge assessment is necessary to be as objective as possible. Starting with experiences obtained by creation of online assessment systems for general chemistry, and from the necessity of a valid and reliable assessment, an auto-calibrated system has been developed. The aim of present research was to assess the microbiology and toxicology knowledge of fourth year students at the Faculty of Materials Science and Engineering from the Technical University of Cluj-Napoca, Romania by using the developed knowledge evaluation system. **Testing System.** Starting from the necessity of a valid (it tests relevant knowledge, skills or abilities) and reliable (the same results would be achieved if the assessment is repeated) assessment method, the proposed evaluation system has been developed as a formative assessment with multiple-choice questions. The testing system comprises two main components: (1) an assessment engine (the hardware and software required to create, store and deliver a test, to create and to store users information and to manage with testing results), and (2) a multiple-choice question bank. A detailed presentation of the assessment engine is presented in [25]. The system has been built up in order to allow: (1) registration of the users; (2) creation of MCQs bank (creation and storing of new questions, and changing of previously created questions); and (3) students' knowledge assessment. The system compute the final mark by auto-calibration, based on all parameters stored into database, being able to display the interest parameters, and to plot the mark distribution. The system also displays all questions included into database as well as the questions with wrong answers. The creation of the multiple-choice questions banking was time-consuming comparing with the creation and configuration of the assessment engine. The students were actively involved into this process of the multiple-choice question banking. Two main rules were imposed here: (1) each question has a statement and a list of five options; and (2) at least one and no more than four options are correct. **Students Sampling and Attendance.** At the Materials Sciences and Engineering Faculty, Technical University of Cluj-Napoca, Romania, the curriculum contains for first semester as core course for the fourth-year of study the Microbiology and Toxicology course. According with course description and with the subject matter, the Microbiology and Toxicology course contains tutorials and laboratory sessions, and at the end of the course the students knowledge are assessed. In the present study were included students from two academic years: 2005-2006 and 2006-2007. All students participated at the lectures and laboratory sessions that included experimental and/or computer aided learning activities. At the beginning of the course, the aim of the research was presented and the students had the possibility to enrol voluntarily into the team responsible with the creation of the multiple-choice questions (MCQs) bank. The Microbiology and Toxicology topics were divided between students enrol in MCQs bank creation, each student or team of two students being responsible with a specific topic. The methodology of MCQ has been presented to the students and they were engaged in creation of proportional number of questions with one, two, three, and four correct options, respectively. The students were informed that if they complete the assumed activities would receive bonus points to the final mark, according with the quality of work. Penalties were applied (a number of points were subtract from the bonus points) when the imposed rules in creation of MCQs were not respected and/or when the created questions were wrong (errors in statement and/or in option(s)). **Testing and Grading Methodology.** The testing methodology imposed: (1) the place of the examination at the test centre; (2) the type of examination as computer- and teacher-assisted; and (3) the number of question per test (thirty). When a test is generated, a double randomization is applied: randomization of the statement, and randomization of the options' order. The students had the possibility to familiarize with the testing system before the examination as many time as they wished. The students had the possibility to test themselves as many time as they desired, in accordance with the imposed period. Penalties were applied any time when students begin a test and give up without responding to questions. The all-or-none rule was applied in grading of students responds (each question received one point if all the correct option(s) and none of the incorrect option(s) were selected). Two scores (the number of correct answers and the average time per correct answer) were took into consideration at the final mark. According with the Romanian Education Law grading mark, and taking into consideration the individual score parameters, the system assigned to the lower score the mark equal with four (the exam is fail) and the highest score to the mark equal with ten (the best mark). The students' marks are auto-calibrated each time when a new test is performed. **Analysis of Results.** A number of variables were collected from each test: students' first and second name, data and time when the test begin and end (yy.mm.dd hh.mm.ss format, where yy = year (e.g. 06 for 2006), mm = month (e.g. 02 for February), dd = day (e.g. 18 for eighteen), hh = hour (e.g. 09 for 9 am), mm = minute (e.g. 12), ss = seconds (e.g. 41)), the number of correct answers, the average time per correct answer, the points of evaluation. Data were collected into a database and were summarized and analyzed with Statistica software at a significance level of 5%. The 95% confidence intervals for proportions were calculated by using of an original method, based on the binomial distribution hypothesis.

Questions Distribution in MCQs Bank

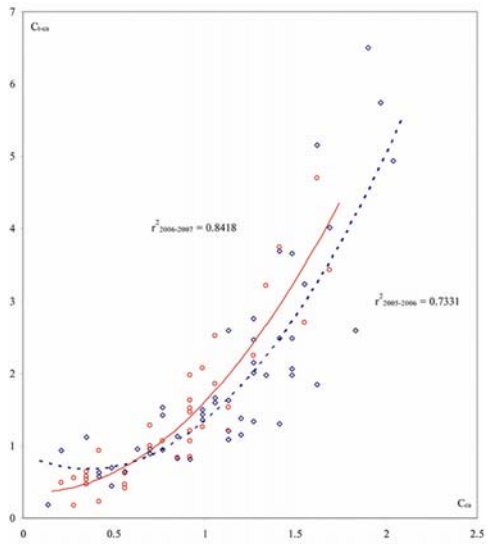
correct option (s)	Academic year 2005-2006 f_a	f_r [95% CI]	2006-2007 f_a	f_r [95% CI]	Total f_a
One	237	65.29 [60.05-70.25]	183	45.19 [40.25-50.12]	420
Two	59	16.25 [12.67-20.66]	88	21.73 [17.78-26.17]	147
Three	38	10.47 [7.71-14.05]	78	19.26 [15.56-23.46]	116
Four	29	7.99 [55.10-11.29]	56	13.83 [10.62-17.53]	85
Total	363	100	405	100	768

fa= absolute frequency; fr = relative frequency; 95% CI = 95% confidence intervals

The Number of Tests Distribution

Tests	Academic year 2005-2006 f_a [95%]	f_r [95%]	2006-2007 f_a [95%]	f_r [95%]	Σ
1	30 [24-34]	78.95 [63.23-89.40]	24 [19-27]	85.71 [67.98-96.3]	54
2	5 [2-11]	13.16 [5.33-28.88]	2 [0-7]	7.14 [0.13-24.87]	7
3	2 [0-7]	5.26 [0.07-18.35]	1 [0-5]	3.57 [0.13-17.73]	3
4	1 [0-5]	2.63 [0.07-13.09]	1 [0-5]	3.57 [0.13-17.73]	2
Σ	38	100	28	100	66

fa= absolute frequency; fr = relative frequency; 95% CI = 95% confidence intervals



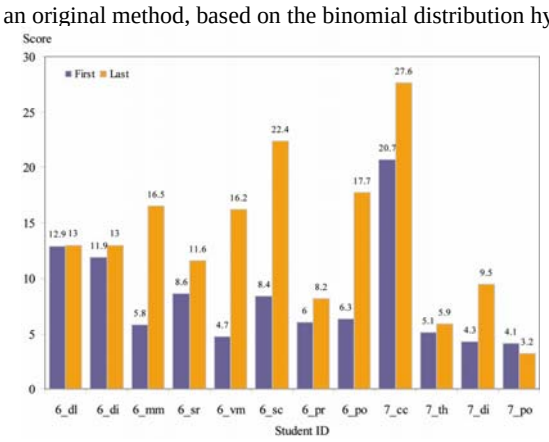
Correct answer score vs average time per correct answer

Correct Answers Scores and Average Time Per Correct Answer: Statistical Characteristics

Tst	Year C_{ca}/C_{t-ca}	nv	Avg	95%^{CI}m	Med	Min	Max	StD
1	2006	38	1.15	[0.99-1.31]	1.13	0.14	2.04	0.48
			2.06	[1.56-2.56]	1.52	0.18	6.50	1.53
	2007	28	0.90	[0.76-1.04]	0.92	0.28	1.69	0.37
			1.47	[1.10-1.85]	1.24	0.17	3.74	0.97
2	2006	8	1.03	[0.69-1.37]	1.17	0.21	1.41	0.40
			1.59	[1.11-2.07]	1.48	0.89	2.49	0.57
	2007	4	0.74	[0.00-1.68]	0.49	0.35	1.62	0.59
			1.72	[0.00-4.89]	0.79	0.62	4.70	1.99
3	2006	3	0.89	[0.00-2.35]	0.70	0.42	1.55	0.59
			1.59	[0.00-5.16]	0.96	0.57	3.23	1.44
	2007	2	0.49	[0.00-3.16]	0.49	0.28	0.70	0.30
			0.92	[0.00-5.55]	0.92	0.55	1.28	0.52
all	2006	50	1.12	[0.99-1.25]	1.13	0.14	2.04	0.47
			1.96	[1.57-2.36]	1.52	0.18	6.50	1.39
	2007	35	0.84	[0.70-0.98]	0.92	0.21	1.69	0.40
			1.44	[1.07-1.81]	1.21	0.17	4.70	1.08

C_{ca} = correct answer score; C_{t-ca}= average time per correct answer; nv = valid sample size; 95%^{CI}m = 95% confidence intervals for mean; StD = standard deviation

Average time per correct answer: first and last evaluation ▲
Scores obtained by students: first and last evaluation ►

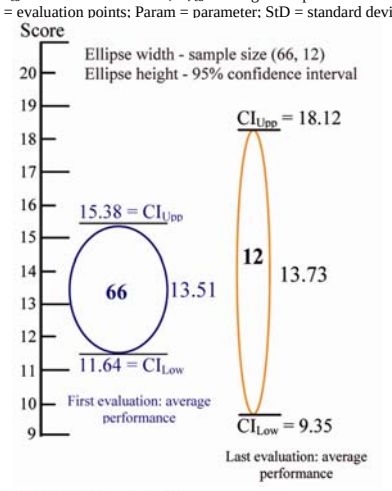


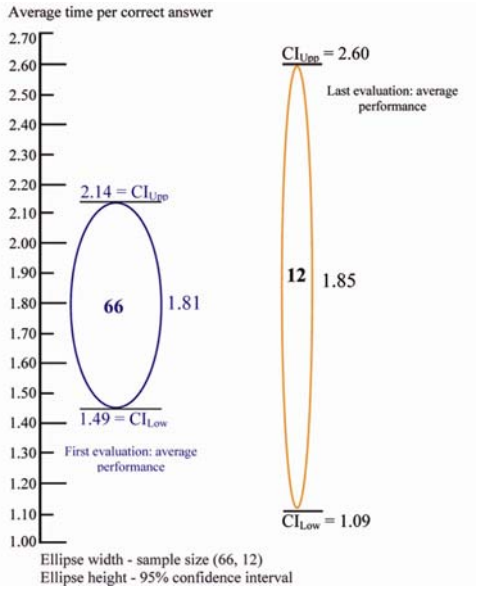
Evaluation scores for sample of students that performed the evaluation more than twice

Parameters for Correct Answers Score, Average Time per Correct Answer, and Evaluation Scores: Single or Twice vs More Than Twice Evaluations

Param	V_n	Mean	95%CI_m	Min	Max	StD
One or two evaluations						
C_{ca}	54	1.12	[1.00-1.24]	0.14	2.04	0.44
C_{t-ca}		1.99	[1.61-2.37]	0.17	6.50	1.38
P_e		14.68	[12.60-16.77]	1.60	35.20	7.63
More than two evaluations						
C_{ca-i}	12	0.75	[0.48-0.92]	0.35	1.34	0.35
C_{ca-f}		1.05	[0.77-1.32]	0.21	1.62	0.43
C_{t-ca-i}		1.00	[0.51-1.49]	0.45	3.21	0.77
C_{t-ca-f}		1.85	[1.09-2.60]	0.49	4.70	1.19
P_{e-i}		8.23	[5.14-11.32]	4.10	20.70	4.86
P_{e-f}		13.73	[9.35-18.12]	3.20	27.60	6.90

C_{ca} = correct answer score; C_{t-ca}= average time per correct answer; P_e = evaluation points; Param = parameter; StD = standard deviation





Once or Twice Tests Versus More Than Twice Tests: Results of Comparison

Param	1/2 Tests n_v	m	StD	≥ 2 Tests n_v	m	StD	t	df	p $\cdot 10^3$
2005-2006									
C_{ca}	30	1.3	0.47	20	0.9	0.39	2.85	48	6.4
C_{t-ca}	30	2.4	1.58	20	1.4	0.75	2.64	48	11.3
P_e	30	17	8.31	20	11	5.28	2.87	48	6.1
2006-2007									
C_{ca}	24	0.9	0.34	11	0.6	0.46	2.40	33	22.3
C_{t-ca}	24	1.5	0.92	11	1.3	1.39	0.66	33	514
P_e	24	12	5.63	11	8.7	7.98	1.34	33	188

C_{ca} = correct answer score; C_{t-ca}= average time per correct answer; P_e = points score; n_v = valid sample size; m = mean; StD = standard deviation; t-value = Student test parameter; df = degree of freedom; p = significance of the student test

2005-2006 Versus 2006-2007 Years: Comparison

Param	2005-2006 n_v	m	StD	2006-2007 n_v	m	StD	t	p $(\cdot 10^3)$	df
C_{ca}	50	1.1	0.47	35	0.84	0.40	2.85	5.50	83
C_{t-ca}	50	2.0	1.39	35	1.44	1.08	1.86	65.9	83
P_e	50	14.6	7.78	35	10.83	6.51	2.33	22.5	83
M_{test}	38	15.8	7.84	28	11.57	6.11	2.34	22.3	64

The access to the e-assessment system is open just from the test centre. A total number of 28 students were involved in development of MCQs banking, 12 out of 38 from 2005-2006 academic year (31.57%, 95%CI [7-18]), and 16 out of 28 from 2006-2007 academic year (57.14%, 95%CI). The distribution of the questions with one, two, three, and four correct option(s) stored into MCQs bank is presented in first Table. The distributions of the number of evaluations expressed as absolute and relative frequencies and associated 95% confidence intervals are presented in second Table.

Discussion

The evaluation of the students' knowledge is an obligatory task at the end of a course for undergraduate students. According with speed, accuracy, objectiveness and fairness, testing methods with multiple-choice questions are frequently used. The presented study revealed that the proposed assessment system on microbiology and toxicology is efficient and effective, the aim of the research being reached. The majority of students performed the test once or twice (see second Table). A simple observation shown that the students that performed the test on 2005-2006 academic year had a large range between first and last evaluations comparing with the ones from 2006-2007 academic year. This could be explained by the interest accorded to microbiology and toxicology topic and/or the students' abilities to work with the e-assessment environment. Generally, the average of correct answers score obtained by students that performed the test on 2005-2006 academic year was greater comparing with the average obtained by students that performed the test on 2006-2007 academic year. The differences vary from 0.4 (for students that performed three tests) to 0.25 (for students that performed one test) (see third Table). As it can be observed from first Fig., there is a strong polynomial relationships between correct answers score and average time per correct answer, showing that, as the average time per correct answer increased the higher the correct answer scores was. As it was expected, with one exception (for the student 7_po), the scores were increasing with the number of tests gave. As the number of evaluations increases, the average time per correct answer increase too, students realizing that the speed is not as important as giving the correct answer (see results of average time per correct answer comparison between first and last test). Looking at the graphical representation of the average time per correct answer scores at first and last tests it can be observed that the upper and lower boundaries are closer tot each other at first evaluation while are far away at the final evaluation. The same observation could be seen for the evaluation scores too (see last Fig). All these observations shown that the students realized that they need to read more carefully the questions and associated option(s) in order to make de correct chooses. The comparison of the performances of students that performed the test on 2005-2007 academic year revealed that the average mean of the correct answers score was significant greater for students that performed the test once or twice comparing with students which performed the test more than twice (see fifth Table). The same observation can be made for average time per correct answers score and evaluation scores. These results could be explained by the students' interest accorded to microbiology and toxicology course, those of them who were not interested presented to the first test hoping to cheat. The same phenomena could not be observed for the students that performed the tests on 2006-2007 academic year. The comparison of the parameters obtained by students that performed the test on microbiology and toxicology on 2005-2006 academic year with those that performed the test on 2006-2007 academic year shown that significant differences are obtained for correct answer scores, average time per correct answer, and the test mean (see last Table). An overall analyzes of the questions and of the tests' difficulties are necessary in order to interpret these differences. As any other computer-assessment methods, the proposed auto-calibrated online system had its advantages over traditional assessment (paper-based). From educational point of view, the main advantage is represented by the active implication of students in creation of MCQs bank. This activity motivates students to ask questions and to find answers, involving them into an active e learning and a real interaction with the teacher, processes useful in acquiring knowledge on microbiology and toxicology. According with the every test evaluation time, the proposed system provide an instant feedback to students, displaying the correct answers score, the number of correct answers and the average time per correct answer. Note that the number of distinct test that can be generated by the system is of C_{768}^{30}, almost $8 \cdot 10^{53}$ distinct tests. From this point of view, the test difficulty could be am important factor of final mark, approach that will be study in future research.

Concluding remarks

The proposed e-assessment system proved to offer a stable and valid evaluation environment on microbiology and toxicology. Students' performances in terms of correct answers score and of average time per correct answer scores revealed to be improved at final evaluation comparing with first evaluation when was applicable, showing an improvement in acquired microbiology and toxicology knowledge. Assessments of the questions and/or test difficulties are necessary to be investigated in order to improve the e-assessment system, this being the aim of our future research.

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