E-Learning and E-Evaluation: A Case Study

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Abstract — **The aim of this paper is to present and analyze an e-learning and e-evaluation project, a framework for training, learning and evaluation. The project was initiated in 2001 in order to develop an educational environment able to bring together virtual experimental applications useful in undergraduate student education. Some e-evaluation systems were also created four years later. The paper describes the design of the e-learning and e-evaluation systems, and presents their applicability.**

Keywords — **e-Evaluation, e-Training, Undergraduate Students.**

I. INTRODUCTION

E-learning and e-evaluation, extensions of information and communication technology, are currently found at all education levels [1]. Due to cost, time, and flexibility for teachers and students, e-learning and e-evaluation have been adopted by many universities for under- and post-graduate student education and evaluation [2]. The techniques have also been adopted by corporations for continuing professional development [3,4].

E-learning facilitates organizational learning, transforming tacit knowledge into explicit knowledge [5], providing wide access [6] and supporting collaborative learning [7]. In e-learning, the students have more educational options and more responsibilities for their own learning [8], active learning being thus promoted [9].

E-learning projects can be found in blended learning strategies (when e-learning methods are used together with traditional educational methods) in undergraduate education for different specialties: medicine [10], electronics [11], engineering [12,13], science learning and teaching [14], business [15,16], and so on.

Evaluation (testing or knowledge assessment) remains an integral part of educational process design for traditional courses as well as for e-learning courses [17]. The main goal of evaluation is to determine whether the educational objectives have been accomplished. Due to their speed, accuracy, objectiveness and fairness [18], online testing and evaluation are frequently used [19,20].

II. PROBLEM AND SOLUTION

At the Technical University of Cluj-Napoca, Romania, Faculty of Material Science and Engineering, most information for students is available only on paper. The curriculum contains courses and practical activities, and

the acquired knowledge is evaluated through exams.

In accordance with the development of information and communication technology, the concepts of training, learning and evaluations changed. More and more information is now available online and the evaluation process changed from paper-based evaluation to computer-based testing.

The objective of the present research was to develop and implement an online interactive educational library for both educational processes: training and evaluation.

The e-training and e-evaluation project is hosted by the AcademicDirect domain and it is available at the following URL: http://l.academicdirect.org/Education/.

III. E-TRAINING

The main objective of the training interface was to encourage an active attitude to learning, asking the right questions, searching for and identifying the proper answer. By using the training environment, the students develop skills that allow them to use a new training environment in order to solve structural and unforeseeable problems for acquiring personal results.

Since the interface must interact with the user in order to implement phenomenological modelling in a friendly environment, the applications give the user a set of basic information, and a set of options (which are in fact the model parameters).

This project, started in 2001, has already implemented six training applications in the field of chemistry. Wherever possible, the URL name of the application is the same with the name of the inventor, or main developer of the device or phenomena.

The *Geiger application* contains two tests whose main purpose is to train the user about the decay rates of main radioactive elements (test1) and about the conservation principles related to nuclear reactions (test2).

The *Gibbs application* uses a small database with substances (a table with eleven substances) and equations (a table with nine reaction parameters) in order to provide the possibility of improving calculation skills for H enthalpy, free G enthalpy and S entropy. The entry in the Substances table contains information about chemical formulas, standard enthalpy and standard entropy, three temperature coefficient values (used to approximate caloric capacity with one of the following formulas: $a+bT+cT^2$ or $a+bT+c/T^2$), and limit temperatures for which the approximation formula remains acceptable. The user has the possibility to choose two reactants from the lists, and then interact with the application to obtain the reaction (or, if the selection is wrong, the message that the reaction is not possible is displayed). After querying the

database, the system also displays a list of possible reaction temperatures. The next page provides the user with calculations for all three energy measures (H, S, G) for all the substances involved at the specified temperatures, the symbolic formulas for calculations of energy measure variations during the reaction, and the calculated values for these variations. Measurement units accompany the displayed numbers.

The *Mendeleev application* is a complex one, with two main training objectives: to help students improved the skills required for obtaining useful information on elements from the periodic system (periodic properties, featured elements and properties) and to convert the right question into a query by using the structured query language (SQL). The system retrieves the answer according to the requested information. A set of five different applications was integrated here. Two tables (one with main information and another with extra information such as measurement units) are behind the interface. Information for every element of the periodic system is stored from numeric (atomic number, mass, boiling point and so on), to characters (Symbol, so on) and to huge text (Discovery, Appearance, Source, and so on). Therefore, in order to find an entity - information related to a chemical element, the user must use the interface and construct the proper query.

The *Milikan application* is about the evidence of electron charge and the use of Milikan's experiment and two physical laws (Coulomb and Newton) in order to find one of (any of) the implied parameters. The application is intended to provide a design solution for the experiment.

The *Reaction Kinetics application* is a simulator for seven types of elementary reactions. It displays the models for every type, and allows the user to select the type, constant rates, initial concentrations of substances, observation time, and number of divisions of the observation time. It computes the time series of the reactants according to the selected model and the product concentrations. After that, it generates a plot with time dependences of the concentrations.

The *Titration application* is a simulator for titration of a weak acid with a weak base. It provides a list of available acids (with known acidity constants) and a list with bases (with known basicity constants), allowing the user to select the quantities and concentrations. Based on the selection of adding a quantity of base over the acid, the pH as function of added volume V is computed. The main problem solved by the application is an equation of rank three. The chemical reaction, chemical parameters and the mathematical model are displayed together with the computed values. Moreover, the user has the possibility to plot the titration curve.

IV. E-EVALUATION

The purpose of the e-evaluation interface is to be used during the evaluation period for testing students' knowledge. In fact, it is an e-training and e-evaluation environment.

The designing of the e-evaluation interface took into consideration the following aspects:

o *Security*

First, to allow the definition of a set of rules which the client computer (user computer) must obey in order to be eligible for use as an evaluation workstation. Rules for information retrieved from the web server were defined. Rule definitions have three specifications ("first", "inside", and "exact"), the meaning of these specifications being that the given variable (which can be, for example, "HTTP_X_FORWARDED_FOR", "HTTP_VIA", "REMOTE_ADDR", "SERVER_ADDR") must be first, inside, or exact with the specified value (example: "172.27.211." first in "HTTP_X_FORWARDED_FOR"). These definitions of set rules have an imposed format (as described above) but do not have minimum or maximum requirements.

Second, to allow the opening and closing of specific actions: view (seen as questions and answers stored into the database), update (allowing modify and insert of questions and answers), test (use of the interface for e-evaluation).

Third, the evaluation must be possible in a secured system, based on two passwords (the student's password and the professor's password, both encrypted in a secured way into the database.

o *Flexibility*

- To allow defining the number of questions that a test will contain.
- To allow defining the Questions & Answers table name, and the name of the discipline.
- To allow defining the end of the evaluation - date and time.
- To allow questions with five possible answers, with one to four correct answers.

A. Training features

The interface was created to serve for both evaluation and training. Thus, users (students) create the questions and answers, having an imposed format (interface), an imposed subject (discipline), and an imposed content (textbook).

The main training features are:

- The students are involved in the task of adding questions to the database, a task which is volunteer;
- The student's work is rewarded through supplementary points added to the final mark.
- The bonus points for this task are given according to the quality of the work. This is an imposed rule, related with the calculation bonus method: the number of correct answers for all inserted questions must have a uniform distribution tendency. The highest bonus can give a plus of 1/5 to the final mark.

A student can take the test as many times as he/she desires, during the evaluation period. Therefore, the student can improve his/her knowledge during the testing period.

The system must encourage the student to use it. Therefore, a "gold feature" offers the user (student) the following possibility: if the test is taken more than once, the final mark is computed from the student's results after

the worst test is withdrawn. This is based on the assumption that everyone must be given an opportunity to get used to the system.

The main objective of the training interface was to encourage an active attitude to learning, asking the right questions, searching for and identifying the proper answer. By using the training environment, the students develop skills that allow them to use a new training environment in order to solve structural and unforeseeable problems for acquiring personal results.

B. Training features

- When modifying and inserting questions, it checks the similarity (using two different similarity algorithms) of the text (question and answers) to be inserted or updated with the text already existent into the database.
- There is the possibility to define two limits for similarity (corresponding to every similarity algorithm). No insert or update is possible if the similarity test fails.

C. General issues

The final mark must take into consideration the abandons (starting of a test and never finishing it). Every abandon is penalized with 1/20 from the final mark.

The student's performance is an average of his/her evaluation results (excluding the worst one, if there are at least two evaluation results).

The final classification for a discipline in a class of students is obtained from the lowest average result (assigned with the lowest classification result), the highest average result (assigned with the highest classification result), and the average of all results.

The system discourages collaboration during the examination and the use of forbidden materials (such as textbooks). A test result is composed of two scores: a time score (total time expended for test answering divided by number of correct answers - i.e. time per correct answer) and number of correct answers. These two scores are averaged in order to give the test result score. The following were observed after using the system on over 298 students: the average time for answering a test was from 15 to 45 seconds per question; in order to pass the examination, the student had to answer at least 30% of questions correctly and had to give a correct answer in at least 90 seconds.

The interface has already been implemented for the following subjects (disciplines): Instrumental Chemistry, Kinetics Chemistry, Materials Chemistry, Pollutants Metrology, and Toxicology.

Details about the system architectures and programs as well as about testing analysis for different disciplines were previously published [21,22].

Each discipline has its own evaluation parameters, such as number of questions in the test, total number of questions into the database, access to the interface facilities (view, update, test) rules and environment variables, date and time of the end of the evaluation (for each academic year).

The interface was developed in order to be used by students at the Technical University of Cluj-Napoca, Romania, thus it is in the Romanian language. What users see for every subject is almost identical (the differences are related only with the subject). Thus, the main navigation panel has a text (a short story) describing the system and the evaluation procedure, including the total number of questions from the database (obtained querying the database), and links to the followings:

- Adding a new user;
- Adding questions;
- Modifying questions;
- Evaluation - testing;
- Evaluation - results;
- List of questions;
- Special characters - an application useful for adding / modifying Romanian characters.

The number of valid multiple-choice questions (n_{MCQB}) stored into the database according to topic and to the number of students that contributed to multiple choice bank creation by using the e-evaluation environment are presented in Table 1-5.

TABLE 1: QUESTIONS CHARACTERISTICS - INSTRUMENTAL ANALYSIS ($n_{MCQB} = 654$).

Param.		No.	%	$^{95\%}CI_{no}$
$n_{c\text{-answer}}$	1	331	50.61	[305 - 357]
	2	155	23.70	[134 - 178]
	3	105	16.06	[87 - 125]
	4	63	9.63	[49 -79]
n_{std}		23	31.94	[15- 32]

Param. = parameter; No. = absolute frequency, % = relative frequency; $^{95\%}CI_{no}$ = 95% confidence interval associated with absolute frequency; $n_{c\text{-answer}}$ = number of correct answer; n_{std} = number of students that created multiple-choice questions; n_{MCQb} = number of question in bank question

TABLE 2: QUESTIONS CHARACTERISTICS - KINETICS CHEMISTRY ($n_{MCQB} = 232$).

Param.		No.	%	$^{95\%}CI_{no}$
$n_{c\text{-answer}}$	1	146	62.93	[131 - 161]
	2	45	19.4	[34 - 58]
	3	22	9.48	[14 - 32]
	4	19	8.19	[11 - 29]
n_{std}		11	45.83	[6 - 16]

Param. = parameter; No. = absolute frequency, % = relative frequency; $^{95\%}CI_{no}$ = 95% confidence interval associated with absolute frequency; $n_{c\text{-answer}}$ = number of correct answer; n_{std} = number of students that created multiple-choice questions; n_{MCQb} = number of question in bank question

TABLE 3: QUESTIONS CHARACTERISTICS - MATERIALS CHEMISTRY ($n_{MCQB} = 863$).

Param.		No.	%	$^{95\%}CI_{no}$
$n_{c\text{-answer}}$	1	297	34.41	[270 - 325]
	2	201	23.29	[177 - 227]
	3	181	20.97	[158 - 206]
	4	184	21.32	[161 - 209]
n_{std}		30	30.3	[21 - 40]

Param. = parameter; No. = absolute frequency, % = relative frequency; $^{95\%}CI_{no}$ = 95% confidence interval associated with absolute frequency; $n_{c\text{-answer}}$ = number of correct answer; n_{std} = number of students that created multiple-choice questions; n_{MCQb} = number of question in bank question

TABLE 4: QUESTIONS CHARACTERISTICS - POLLUTANTS METROLOGY ($n_{MCQB} = 439$).

Param.		No.	%	$^{95\%}CI_{no}$
$n_{c\text{-answer}}$	1	154	35.08	[135 - 175]
	2	101	23.01	[84 - 120]
	3	100	22.78	[83 - 119]
	4	84	19.13	[69 - 102]
n_{std}		19	48.71	[21 - 40]

Param. = parameter; No. = absolute frequency, % = relative frequency;
$^{95\%}CI_{no}$ = 95% confidence interval associated with absolute frequency;
$n_{c\text{-answer}}$ = number of correct answer;
n_{std} = number of students that created multiple-choice questions;
n_{MCQb} = number of question in bank question

TABLE 5: QUESTIONS CHARACTERISTICS – TOXICOLOGY ($n_{MCQB} = 767$).

Param		No.	%	$^{95\%}CI_{no}$
$n_{c\text{-answer}}$	1	419	54.63	[391 - 446]
	2	147	19.17	[126 - 170]
	3	116	15.12	[97 - 137]
	4	85	11.08	[69 - 104]
n_{std}		28	43.75	[20 - 36]

Param. = parameter; No. = absolute frequency, % = relative frequency;
$^{95\%}CI_{no}$ = 95% confidence interval associated with absolute frequency;
$n_{c\text{-answer}}$ = number of correct answer;
n_{std} = number of students that created multiple-choice questions;
n_{MCQb} = number of question in bank question

The questions with none correct answers or with five correct answers were not included into the bank from where the tests are generated.

Two questions from materials chemistry were excluded (one without a correct answer and one with five correct answers), four questions from pollutants metrology (three without a correct answer and one with five correct answers) were also excluded, and so were two questions from toxicology (both of them without a correct answer).

The distribution of the students that used the e-evaluation systems according to topic and academic year is presented in Table 6.

The statistical characteristics of time per correct answer, number of correct answer and bonus according to discipline and topic are presented in Table 7 - 10.

TABLE 6: E-TESTING USAGE VERSUS NUMBER OF STUDENTS.

Topic	Academic year				Total	
	2005-2006		2006-2007			
	$n_{e\text{-test}}$	n_{std}	$n_{e\text{-test}}$	n_{std}	$n_{e\text{-test}}$	n_{std}
Instrumental Analysis	86	42	47	30	133	72
Kinetics Chemistry	n.a.	n.a.	35	24	35	24
Materials Chemistry	236	99	n.a.	n.a.	236	99
Pollutants Metrology	n.a.	n.a.	69	39	69	39
Toxicology	80	37	55	27	135	64
Total	402	178	206	120	608	298

$n_{e\text{-test}}$ = number of e-testing usage; n_{std} = number of students;
n.a. = not applicable

Note that all the evaluations student were included into

TABLE 7: INSTRUMENTAL ANALYSIS: STATISTICAL PARAMETERS OF EVALUATIONS.

	Correct answer		Time per correct answer (seconds)		Bonus	
Year	2006	2007	2006	2007	2006	2007
n_{valid}	61	32	61	32	12	8
μ	6.84	15.63	126.92	44.35	0.91	0.71
SD	3.65	7.12	79.27	61.97	0.94	0.6
Me	6	14.5	111.1	21.7	0.41	0.55
Min	1	2	19.7	4.8	0.2	0.14
Max	17	28	396.4	295	2.62	1.75

Year = year of evaluation; n_{valid} = sample size;
μ = arithmetic mean;
SD = standard deviation; Me = median

TABLE 8: TOXICOLOGY: STATISTICAL PARAMETERS OF EVALUATIONS.

	Correct answer		Time per correct answer (seconds)		Bonus	
Year	2006	2007	2006	2007	2006	2007
n_{valid}	50	35	50	35	12	16
μ	15.94	11.83	40.66	61.84	0.69	1.12
SD	6.62	5.73	39.98	57.28	0.47	0.52
Me	16	13	32.65	46.7	0.53	1.14
Min	2	3	7.6	10.5	0.21	0.32
Max	29	24	273.5	290	1.68	1.91

Year = year of evaluation; n_{valid} = sample size; μ = arithmetic mean;
SD = standard deviation; Me = median

TABLE 8: KINETICS CHEMISTRY: STATISTICAL PARAMETERS OF EVALUATIONS.

	Correct answer	Time per correct answer (seconds)	Bonus
Year	2007	2007	2007
n_{valid}	27	27	12
μ	9.37	86.63	0.34
$_{95\%}CI$	[7.99 - 10.75]	[67.36 - 105.91]	[0.10 - 0.57]
SD	3.49	48.72	0.36
Me	10	71.7	0.33
Min	4	16.8	-0.5
Max	15	224.2	0.89

Year = year of evaluation; n_{valid} = sample size;
μ = arithmetic mean;
SD = standard deviation; Me = median

TABLE 9: POLLUTANT METROLOGY: STATISTICAL PARAMETERS OF EVALUATIONS.

	Correct answer	Time per correct answer (seconds)	Bonus
Year	2007	2007	2007
n_{valid}	43	43	17
μ	10.28 [8.31 - 12.25]	88.97 [61.26 - 116.69]	1.53 [1.21 - 1.85]
$_{95\%}CI$			
SD	6.41	90.05	0.62
Me	8	60.8	1.83
Min	2	15.6	0.2
Max	24	478.5	2.15

Year = year of evaluation; n_{valid} = sample size;
μ = arithmetic mean; SD = standard deviation; Me = median

The maximum number of correct answers varied from 1 to 30 (each test had 30 multiple choice questions) as it can be observed from Table 7 - 10.

	Correct answer	Time per correct answer (seconds)	Bonus
Year	2006	2006	2006
n_{valid}	149	149	24
μ $_{95\%}$CI	21.85 [20.65 - 23.06]	21.86 [17.72 - 26.00]	1.90 [1.45 - 2.35]
SD	7.45	25.58	1.07
Me	24	11.5	1.93
Min	1	3.3	-0.5
Max	30	142.9	4

Year = year of evaluation; n_{valid} = sample size;
μ = arithmetic mean; $_{95\%}$CI = 95% confidence intervals for mean;
SD = standard deviation; Me = median

Statistically, the mean of correct answers obtained by students that took the test in the academic year 2005-2006 (abbreviated as 2006 in Table 7 - 10) was significantly lower (up to eight correct answers) compared with the students that took the test in the academic year 2006-2007 (abbreviated as 2007 in Table 7 - 10) ($p < 0.001$). Although the difference was not so high for the students that took the Toxicology test (up to four correct answers), the same observation as in the case of Instrumental Analysis could be done ($p < 0.004$), but this time the students from the academic year 2005-2006 scored better. The time per correct answer was significantly higher for the students that took the Toxicology test in the academic year 2006-2007 (with almost twenty-two seconds) compared with those that took the test in the academic year 2005-2006 ($p = 0.0478$).

Also, the average time per correct answer was significantly higher for the students that took the Instrumental Analysis test in the academic year 2006-2007 (almost eighty-three seconds) compared with those that took the test in the academic year 2005-2006 ($p = 0.000002$).

The students that took the Materials Chemistry test obtained the lowest value for time per correct answer (an average of 21.86) and the highest value for correct answers (almost twenty-two correct answers on average). Applying the Pearson correlation coefficient on performances obtained by these students a value of -0.72 ($p < 0.05$) was obtained.

Regarding the bonus obtained by students it can be observed from Table 7 - 10 that, with two exceptions (Pollutants Metrology & Materials Chemistry) the average values were less than 1. On these topics the questions were constructed by the teacher and volunteers introduced them into the system (for this activity they received extra-bonus points). The negative values are penalties and were applied to students that started a test and never ended it or to students that created questions without a correct answer or with five correct answers.

V. PARTICULARITIES AND FUTURE DEVELOPMENT

A lot of online-training and evaluation systems are available today in different domains of interest. The students lose their interest in paper-based books and libraries because they are able to find the information faster by searching on the Internet or by using an electronic book.

The presented project has some particularities that are not related to the e-training environment but to the e-evaluation environment. As already presented, the e-evaluation environment was constructed as a training and evaluation instrument. The active involvement of the students in the creation of multiple-choice banks introduces a new method of learning. This activity motivates students to ask questions and to find answers, thus involving them into an active learning process and an active interaction with the teacher, which are useful for their development. Some specifications regarding the e-testing environment must be done:

o The time needed to evaluate each test is considerably small (which represents an advantage when testing large classes);

o The evaluation is as objective as it could be;

o The idea of cheating by looking for the correct answer (the marking depends on the number of correct answers as well as by time per correct answer) or by asking a colleague (the number of distinct tests that can be generated for Toxicology for example is of C_{767}^{30} which is equal with $7.42 \cdot 10^{53}$) are discouraged;

o Basic computer skills are necessary in order to use the system. This could be a disadvantage in a country like Romania, because every student is able to write a paper-based exam but there is no certitude that every student knows how to work with a computer.

A hard work must be done for the development of the e-learning and e-evaluation project. The learning environment could be improved by increasing the number of applications available and by creating a virtual experimental environment. The e-evaluation environment could be developed by increasing the number of disciplines and by homogenization of questions stored into the database. All these could be done with proper financial support and the active involvement of professors and students.

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