Administration of Knowledge Assessment at Riga Technical University

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***Abstract*—This paper is devoted to administration of students' knowledge assessment at the Faculty of Computer Science and Information Technology of Riga Technical University. The faculty uses a number of computer-based software systems for this purpose. The goal of the research is to evaluate them from the perspective of their usefulness for administration of students' knowledge assessment. This paper provides description of each system and the results of the analysis made on the basis of the experts' survey.**

Keywords- computer-based learning; knowledge assessment; experts' survey

I. INTRODUCTION

Due to the rising speed of scientific and technical progress, the volume of knowledge and skills needed by contemporary specialists is continuously growing. This substantially increases requirements in relation to organization of the study process in educational institutions and especially to selection of an appropriate knowledge assessment strategy. Nowadays, computer-based knowledge assessment is of special interest because it allows administration of knowledge assessment activities at all stages of the study process, it substantially reduces both workload of teachers and time spent for preparation and evaluation of students' assignments, as well as it assures the objectivity of assessment process.

The Faculty of Computer Science and Information Technology of Riga Technical University (RTU) is not an exception. Its staff is making research in the field of computer-based learning already for 40 years. Today, both traditional methods of knowledge assessment and computer-based software systems (electronic textbooks, the learning management system, the Moodle-based e-learning environment, and the concept map based intelligent knowledge assessment system) developed for this purpose are used in the educational process.

The goal of the research presented in this paper is to evaluate the developed computer-based software systems from the perspective of their usefulness for administration of students' knowledge assessment. This paper contains description of the mentioned systems, as well as results of their analysis and comparison.

This paper is organized as follows. Section II presents a brief overview of related works. Section III contains descriptions of the software systems used in the study process at the faculty. Section IV presents research methodology and results of the analysis made. Conclusions are given at the end of this paper.

II. RELATED WORK

Many international scientific conferences (such as IEEE ICALT, IADIS e-Learning, IASTED CATE, etc.) and e-journals [5][6][7] are dedicated to research in the field of computer-based learning and knowledge assessment.

Researchers in this field are developing and implementing new methods of knowledge assessment [1][2][3][4]. The implementation of these methods can be found in modern e-learning systems. Latest research indicates that the use of such systems has a positive effect on students' progress in studies, it increases their motivation, and they appreciate this kind of approach to learning process [16][17][18].

However, the evaluation of e-learning systems from the perspective of students' benefits doesn't let to evaluate the usefulness of these systems for students' knowledge assessment. That's why this paper aims to compare e-learning systems that are used in RTU and to determine whether they are close to the benchmark – the model of an ideal system, which is based on the features chosen by experts.

III. SOFTWARE SYSTEMS USED IN THE STUDY PROCESS

A. The Electronic Textbook for HTML Language

The electronic textbook "Learn HTML from scratch" is a computer-based learning program, which includes eight topics on HTML language: structure of a document, text, graphics, references, tables, frames, styles, and dynamic HTML [8]. Each topic contains theoretical material supplemented by several examples and a series of assessment questions. Fig. 1 displays the structure of the electronic textbook.

Three modes of operation (self-assessment, testing, and reference mode) and a variety of knowledge assessment methods and models [9] are implemented in the electronic textbook. Two types of questions (multiple choice questions and text/numerical input) are available for assessment activities.

A method called "Strict sequence" is used in the mode of self-assessment. It means that a set of assessment tasks is prepared prior to the test and tasks are offered to all students in the form of the same fixed set. In this mode, students answer questions and receive a short overview of their performance (number of correct answers, time for completing a specific task, and average score).

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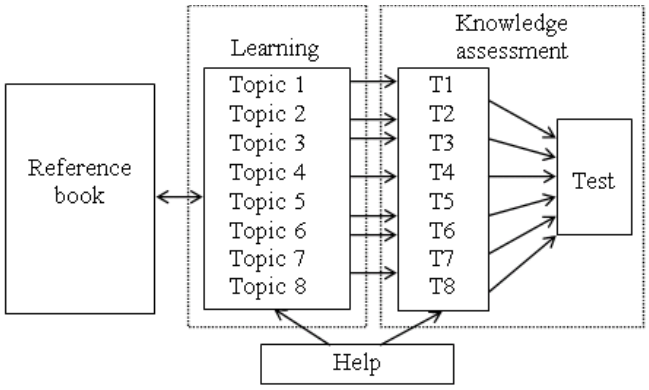

Figure 1. Structure of the electronic textbook.

In the testing mode, a method called "Random selection" is used for creating and issuing a set of assessment tasks. Therefore, the set contains *n* tasks, which are selected in a random fashion from a task pool.

A test for final examination is implemented in the textbook. It is composed of questions from all eight topics. Therefore, it allows assessing of students' knowledge in relation to the whole course. A set of assessment tasks is formed suing the method "Strict sequence".

Student's score is the average score obtained taking into account the student's number of correct answers and completion time of assessment tasks.

The electronic textbook „Learn HTML from scratch" was applied as a learning tool in the course "Development of Web Applications for Internet". Results of the research made in 2003 showed that students actively used the textbook both for learning and for knowledge assessment [10]. However, the electronic textbook had a number of significant drawbacks: a) it could be used only for one study course, b) learning materials (content of topics, sections, examples, and a set of assessment tasks) were embedded into the book, thus, making difficult their modifications and changing, and c) the electronic textbook was available for use only from RTU local network. However, the major disadvantage was related to usage of inappropriate methods („Strict sequence" and „Random selection") for forming a set of assessment tasks for continuous and final assessment [11].

B. The Universal Electronic Textbook

The universal electronic textbook was developed in 2005. The drawbacks of the previous book were eliminated and its functionality was extended [12]. Fig. 2 shows the structure of the universal electronic textbook.

The textbook allows the teacher a) to develop new courses by determining their structure - number of sections and topics, b) to change and/or to add learning materials of a course, c) to create a set of assessment tasks, d) to choose a topic or topics for knowledge assessment, and e) to obtain assessment results of a student or a group of students. The main advantage of the universal electronic textbook is a teacher's possibility to administer different types of knowledge assessment: prior, continuous, and final assessment.

In assessment of prior knowledge, the methods "Strict order" and "Random selection" are used for creating and issuing a set of assessment tasks. They were selected on the basis of recommendations concerning usage of different methods for creation of a set of assessment tasks in different types of knowledge assessment. Recommendations were acquired through the experts' survey presented in [11]. In the universal electronic textbook, the teacher can perform continuous and final knowledge assessment according to the sequence, in which learning material was mastered by preparing a test from assessment tasks related to one or more topics.

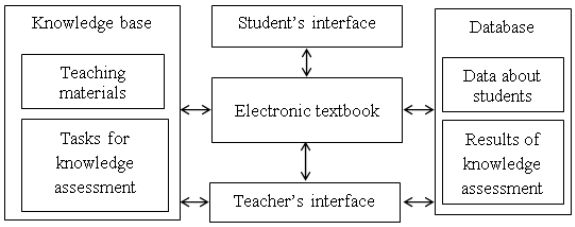

Figure 2. Structure of the universal electronic textbook.

With the help of the universal electronic textbook a student can master a chosen study course (learning mode), as well as he/she can assess knowledge in a particular topic or in the entire course (testing mode). Two types of questions are used: multiple choice questions and text/numerical input. However, comparing with the first electronic textbook, this book allows the teacher to specify the difficulty level of an assessment task (minimal, average, or maximal).

The mentioned textbook was used in the study course „Development of Web Applications for Internet" from 2005 till 2007.

C. The Learning Management System

Learning Management System (LMS) [13] includes two modes of operation that are directly related to knowledge assessment: random selection of tasks and/or questions for assessment and training mode (Fig. 3). Both modes can be used for knowledge self-assessment as well.

The mode of the random selection uses the non-adaptive assessment method. In this case the number of questions for knowledge assessment in a group of students is defined by the teacher, who also determines the number of tasks of different difficulty level (maximal, average, or minimal), which should be included in each set of assessment questions. Moreover, the teacher specifies type of comments, which will be provided as a reaction to student's answers: short (right, partly right, or wrong) or detailed with explanation of a mistake made. In case of self-assessment, the student chooses and sets these parameters by him/herself.

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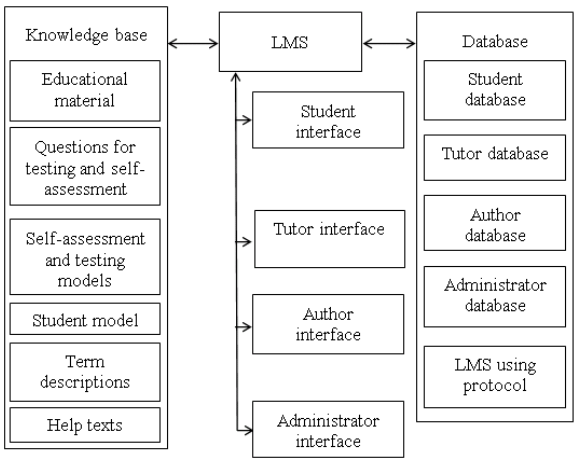

Figure 3. Structure of the LMS

Depending on the choice, the training mode performs non-adaptive assessment, when the student completes either all or a selected number of assessment tasks, or partly adapted assessment (taking into account student's answers), when the number of tasks provided to the student depends on his/her overall success. In this mode, type of comments, which will be provided by the system, can also be chosen.

After completion of the test, the student gets a grade, which takes into account both correctness of answers and difficulty level of questions.

At present, the LMS includes 9 e-courses related to the study courses „Software Engineering", "Software Metrology and Planning", "Software Development Tools and Environments", and "Programming Languages". During the period from 2004 till 2006, students had possibility to use the courses included in the system for self-assessment, training, and/or learning. Since 2007, students' knowledge assessment in the mentioned courses is compulsory and is usually performed during practical assignments in class. Usually, each student receives from 8 to 10 assessment tasks. At the same time, in order to improve the grade in a test, students are allowed to take the test repeatedly in 2 days' time. In this case the grade is determined by the teacher. Students can also use other modes of system's operation at any time.

D. ORTUS Portal

RTU has developed the portal ORTUS, which provides administrative, scientific, and educational support for students and university staff. One part of this portal is a Moodle-based e-learning environment that allows creation of e-learning courses starting from uploading of different learning materials and finishing with developing tests and administering knowledge assessment activities.

ORTUS portal has been used in the study process since 2008. In relation to knowledge assessment, the teacher can create a test, set the time for its completion and the number of attempts. The test can be completed in class (one attempt) or at a distance (more than one attempt). It is possible to create tests from different categories and types of questions. All together, 10 types of questions are available. The teacher has possibility to assign number of points for each question taking into account its difficulty level. Comments for all kinds of questions are envisaged. The only drawback of the ORTUS e-learning environment is availability of only one method of knowledge assessment, namely, "Random selection".

E. IKAS system

IKAS is a web-based intelligent knowledge assessment system, which is intended for assessment of students' structural knowledge through the use of concept maps [14]. It has been developed since 2005 and, therefore, the system is described in many publications, for example [3][15][16]. As a result below only the general overview of the system is given.

The main goals of the system are the following: a) to promote students' structural knowledge self-assessment and b) to support teachers in improvement of study courses through systematic assessment and analysis of students' knowledge structures. Knowledge self-assessment is supported by automatic evaluation of students' concept maps and provision of informative and tutoring feedback. Systematic knowledge assessment is based on the possibility to extend an initially created concept map for other assessment stages. Statistics on differences between students' and teacher's concept maps allow teachers to improve their courses.

IKAS supports three categories of users: a) an administrator, b) a teacher, and c) a student. The administrator prepares the system for use by other users and manages its default parameters and data related to knowledge assessment process and its participants. Activities directly related to knowledge assessment are split between the teacher, the student, and the system and they include: 1) creation of a concept map by the teacher; 2) reproduction of the teacher's concept map by the student during completion of concept map based tasks; 3) comparison of the teacher's and student's concept maps by the system; 4) generation of feedback by the system.

Six tasks of different degrees of difficulty are implemented. Four of them are 'fill-in-the-map' tasks where an obligatory component is the structure of a concept map, which must be filled-in by students using available concepts and/or linking phrases. Last two tasks are 'construct-the-map' tasks where the student constructs a concept map from provided concepts and/or linking phrases. Ten transitions between tasks are realized: five of them increase the degree of task difficulty and another five reduce it.

The system provides rich student's support and includes a number of adaptive, adaptable, and intelligent features. Student's support is comprised of possibility to change the degree of task difficulty, to insert in automatic way some concepts into the provided structure of the concept map, to explain a concept, to check a created proposition, as well as quantitative data (like score received, time spent, number of help used, etc.) and qualitative data (concept mastering degrees, individual study plan). The main task of the system

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is to perform automatic evaluation of students' concept maps. This is done in intelligent way by using the teacher's concept map as a reference map and a comparison algorithm that is based not only on the isomorphism of both graphs representing concept maps, but which is sensitive to the arrangement and coherence of concepts in students' concept maps and is capable to recognize partly correct patterns of a student's solution. Operation of the IKAS is based on interpretation of values of parameters available in a student model. The student model supports four adaptation operations in the IKAS: selection of the initial degree of task difficulty at the first assessment stage and its changing at next assessment stages, as well as setting and changing priorities of types of concept explanation. Adaptable features of the system available to students include the following ones: 1) adjusting the degree of task difficulty by directly changing the knowledge level of the course in the student model or reducing the degree of task difficulty during the completion of CM based tasks; 2) adjusting settings of the user interface such as language, theme, etc.; 3) changing approach for receiving of explanations and priorities for different types of concept explanation.

Since 2005, IKAS has been evaluated in more than 20 courses. Typically the system is used in content-rich courses, which include a lot of closely interrelated concepts, for example, "Fundamentals of Artificial Intelligence", "Methods of Systems Theory", "Discrete Structures in Computer Science". As a rule, a teacher prepares a concept map for a logically completed part of a course (module or topic block) and gives it to students at the end of this part. After completion of concept map based tasks by students, the teacher examines statistical data about students' incorrect or missing relationships and makes corrections in further curriculum of the course. Therefore, during the course students work with concept maps 3-4 times.

F. Summary of the Described Systems

Table 1 specifies the main characteristics of the previously described software systems. These systems are successfully used at the Faculty of Computer Science and Information Technology of RTU for knowledge assessment and self-assessment in the following study courses: "Data Structures", "Programming Languages", „Software Engineering", "Software Metrology and Planning", "Fundamentals of Artificial Intelligence", "Methods of Systems Theory", "Discrete Structures in Computer Science", etc. Results of the research presented in [16][17][18] show how use of the systems improves progress of students, motivates students, and increases quality of their knowledge at a stage of the final knowledge assessment (examination).

IV. Analysis of the Systems

The next sections discuss the methodology and results of the research.

A. Research Methodology

During the research presented in this paper the experts' survey was performed with aim to determine features of e-learning systems, which are most significant for knowledge assessment. The group of experts was selected by studying literature in the field of e-learning and through direct communication between the authors of this paper and experts at international workshops and conferences devoted to problems of computer-based knowledge assessment. As a result, nine experts participated in the survey.

The questionnaire used in the survey asked experts to evaluate importance of different features of e-learning systems, e.g. the processing of student's answer given in natural language, the management of knowledge assessment on the bases of mathematical models, etc., in relation to administration of students' knowledge assessment in such systems. Thirty features were included. Authors offered the following scale for evaluation of importance of each feature:

- 10 – an important and useful feature, but it is possible that it cannot be implemented at the moment (such features should not be in a large number);
- 8 ÷ 6 – a feature, which can be implemented and should be implemented in the system;
- 4 – a useful, but not so important feature (moreover, it can be easily implemented);
- 1 ÷ 2 – a feature, without which the quality of the system will not suffer significantly;
- 0 – a useless feature.

Data acquired through the questionnaire were processed in 2 stages. First of all, the coefficient of concordance *W* characterizing agreement between experts was calculated taking into account the methodology presented in [19].

After that, importance *(Sj)* of each feature of e-learning systems was identified and the list of features in the decreasing order (the most important feature has the smallest *Sj* value) was created.

At the end, the ordered list of features was used for evaluation of software systems described in this paper. For this purpose the following indicator was introduced:

$$Z = \sum_{j=1}^{n} S_j C_j \ , \qquad (1)$$

where S_j – importance of *j*–th feature; C_j – the coefficient characterizing extent of implementation of the feature in a system under evaluation, the value of this coefficient is determined by the reviewer of the system and depends on the level of feature implementation, but the range of values is permanent: $C_j = [0..1]$.

The authors of this paper determined the following levels of feature implementation:

- if a feature is fully implemented in the system, then $C_j = 1$;
- if a feature is implemented, but it has some shortcomings, then $C_j = 0.8$;
- if a feature is under implementation, then $C_j = 0.4$;

- if a feature is not implemented, then $C_j = 0$.

Further an indicator of relativity z was calculated:

$$z = \frac{Z}{Z_{\text{benchmark}}} \quad (2)$$

It characterizes the degree of compliance of a system under evaluation to a benchmark. The benchmark is calculated when values of the coefficient for all features are equal to 1. The value of the coefficient z is in the range from 0 to 1. The closer this coefficient is to 1, the closer the system is to the ideal system.

B. Results of the survey

The range of values for the coefficient of concordance W can vary from 0 to 1. In our case W = 0.64, so we can conclude that the agreement between experts is high. The involved experts considered the following features as the most important ones:

- Management of the knowledge assessment process on the basis of mathematical models;
- Possibility to analyze different types of answers (word, phrase, hotspot on an image, etc.);
- System's openness for further improvements and development;

TABLE I. SUMMARY OF SYSTEMS

	Electronic Textbook	Universal Electronic Textbook	LMS	ORTUS	IKAS
Users	Student	Student; Teacher	Student; Teacher; Author; Administrator	Student; Teacher	Student; Teacher; Administrator
Courses	HTML language	Any course	Any course	Any course	Any course
Mode	Testing; Reference; Self-assessment	Learning; Testing	Random selection of tasks and/or questions for assessment; Training; Self-assessment	Training; Knowledge assessment	Knowledge assessment; Knowledge self-assessment with tutoring component
Methods	Fixed sequence	Fixed sequence; Random selection	Fixed sequence; Random selection	Random selection	The student starts with teacher's specified degree of task difficulty. Further the degree can be changed on the basis on student's request or in adaptive manner
Adaptive knowledge assessment	No	No	No	Yes	Yes
Task type	Multiple choice questions; Text/numerical input	Multiple choice questions; Text/numerical input	Multiple choice questions; Multiple response questions; Matching; Text/numerical input	Description; Essay; Multiple choice questions; Multiple response questions; Matching; True/False; Text/numerical input; Equation input; Sentence input	"Fill-in-the-map"; "Construct-the-map"

- Possibility of using data from a domain model during knowledge assessment;
- Possibility of performing adaptive knowledge assessment;
- Support of different types of users (student, author, teacher, administrator, etc.).

As the most unimportant features the experts mentioned the following ones:

- System's functioning in a network (Internet, a local network, etc.);
- Provision of the certain response time to users' actions;
- Possibility of using of probabilistic assessment models.

Table II presents results of evaluation of the software systems taking into account the coefficients *Z* and *z*.

TABLE II. RESULTS OF EVALUATION

	Electronic Textbook	Universal Electronic Textbook	LMS	ORTUS	IKAS	Benchmark
Z	64.8	136.4	209.6	298.4	242.6	465
z	0.14	0.29	0.45	0.64	0.52	1

The systems "Electronic Textbook" and "Universal Electronic Textbook" received the smallest evaluation (z=0.14 and z=0.29 accordingly), but ORTUS portal is closest to the benchmark (z=0.64).

CONCLUSION

Taking into account experts' opinion about the most important features of e-learning systems for students' knowledge assessment, the methodology for the usefulness

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evaluation of such systems were developed. This methodology can be used in a combination with other methodologies for the evaluation of any e-learning system, as well as for comparison of this kind of systems between themselves. Five systems for administering students' knowledge assessment were evaluated using the developed methodology. Evaluation results showed that ORTUS and IKAS are the closest to the benchmark. These systems implements methods of adaptive assessment of students' knowledge, and they are open for further improvement and development. Therefore, the further work will be related to the improvement of ORTUS and IKAS considering the list of the most important features for knowledge assessment, determined by experts.

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