

Development of an electronic system for remote assessment of students' knowledge in cloud-based learning environment

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Abstract. The system for remote assessment of knowledge automates formation of task (tickets) with questions and tasks for conducting intermediate and final monitoring of knowledge of students is offered. In the process of developing an electronic system for knowledge assessment, the basic requirements for a web application and the modules that the system consists of were determined, the main roles of users in the system and their functionality were identified, access rights were established. The technical, functional, and non-functional features of the software product are described, web technologies for creating an application for knowledge assessment are considered. The diagram of system sequences, the use-case diagram, which schematically describing roles and functions of agents in an information system, the diagram of classes of a database structure are presented with UML description. Based on the defined requirements for the resource in cloud-based learning environment, the following technologies for its development were chosen: the server programming language PHP, JavaScript programming language and its libraries were used, as well as the MySQL database with PhpMyAdmin tool for administration of chosen database management system. OpenServer software complex system was used to develop and test the application functionality. The usage of the proposed electronic assessment system of knowledge contributes to the formation of an open information and cloud-based learning environment of a modern educational institution, enhances the efficiency and more rational distribution of teacher time in preparing tests or exams, activates repetition of educational material and knowledge assimilation, indirectly motivates students to more honest learning.

Keywords: Knowledge Assessment, e-Assessment, Monitoring of Knowledge, Web Application, Distance Learning

1. Introduction

Control of students' knowledge and skills is an important component of the cloud-based learning environment, which should be conducted throughout the educational period. The assessment of students' level of knowledge depends, for example, on the motivation of students to acquire

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knowledge, the desire for in-time quality performance of exercises set by the teacher. In 2020, the governments of more than 190 countries closed their educational institutions in order to prevent the rapid spread of COVID-19 [10]. With the changeover of educational institutions to distance learning, the problems of timely, objective and sound assessment and monitoring of student achievements in the digital space is becoming increasingly important and requires such forms and methods of solution, as cloud-oriented learning systems.

2. Related work

The assessment of students' academic achievements is understood as a system of indicators that reflect their objective knowledge and skills, that is this process can be considered as determining the degree of acquisition of knowledge, skills and achievements in accordance with the requirements of the curriculum [21].

The assessment consists of such components as a score, which is an actual fixed value that describes the level of student achievement, his skills, abilities, and may contain the teacher judgments about the characteristics of student achievement while education period, what disadvantages and achievements were formed during this process.

Due to the closure of university campuses and the necessity to maintain social distance, world organizations such as UNESCO [27], the International Association of Universities [16], the OECD Center for Educational Research and Innovation [17], OECD Education and Skills Today [28] began to work actively on the development of solutions for the organization of online examinations of students.

However, even before the COVID-19 pandemic, the benefits and strategic directions of using e-assessment were discussed in the works of Alruwais, Wills and Wald [1], Arend [2], Crisp [6], Guàrdia, Crisp and Alsina [11], Shalatska et al. [22].

Issues of analysis and assessment of student achievement during distance learning and cloud technologies were studied in the works of Bondarchuk et al. [3], Harrison and Hutton [12], Kiv et al. [13], Kostikov et al. [14], Proskura, Lytvynova and Kronda [18], Samchynska and Vinnyk [19, 20], Sherman and Samchynska [23], Spivakovskiy et al. [24], Todeush and Sherman [25], Tomaino et al. [26], Vincent-Lancrin [28], Wang [29], Wijekumar, Ferguson and Wagoner [30], Zaytseva [31].

OES is the complex platform – online examination system, which has been developed in PHP script with MySQL Database [7]. This system is aimed at automated creation of tests for the exam based on questions, which are already entered in the database. The OES platform is capable to identify the strengths and weaknesses of the student after passing the exam tests. The disadvantage of this system is that it supports different types of questions, so it can generate only the tests with one or more answers.

ConductExam platform is an online examination software that includes a large combo of software applications for web-based exam software, offline exam, computer-based test, control-based exam, online assessment software, and many more [5]. With this system, teachers can add questions or tasks. The student has the opportunity to take the exam on the Internet in accordance with the specified date, time and with the help of a registered login ID and secret key. However, the capabilities of this platform do not include an automatic parsing of questions

from training educational materials files.

The system of online education of Kremenchug Mykhailo Ostrohradskyi National University contains a testing system with which teachers can create courses, test tasks, conduct exams and assess the quality of students' knowledge [15]. Applicants for higher education can take exams in the form of tests, communicate with teachers online and receive advice. The system supports only test tasks.

The considered systems of knowledge assessment do not have sufficient flexibility in the formation of questions and tasks of different types, the functionality does not provide information about the results of students' completed tasks, and does not contain an automated selection of questions from different types of documents. Therefore, these features and capabilities need to be considered when developing an advanced online system for knowledge assessment.

3. Research questions

In the circumstances of distance learning there appear certain difficulties and consequently drawbacks in the assessment of educational achievements of higher education students. They are associated with insufficiently objective and non-transparent assessment and recording of the level of knowledge acquired by the student during the education period, insufficient attention to the individual achievements of the student, technical difficulties in creating quality e-tickets, tests and other control tasks.

Concerning the features of electronic assessment of higher education applicants' achievements, ensuring its quality and objectivity require a description of the technical characteristics of the information system, functional and non-functional parameters of the software product to provide an online assessment of the acquired knowledge level.

The development and use of a web application for online assessment of higher education as a part of a sophisticated system of monitoring the levels of higher education applicants' achievements, which is being developed at Kherson State University, will help to improve the process of assessing students' knowledge and skills during distance learning.

The aim of the study is the development of an electronic system for assessing the level of knowledge, which automatically generates tickets, tasks for tests, exams and other control measures in the form of a web application for remote assessment of the level of knowledge acquired by students.

The following *research tasks* were set:

1. To determine the requirements that must be met by an electronic system of remote knowledge assessment.
2. To choose methods of generating control tasks (tickets) using web technologies.
3. To define the architecture and describe the modules of the electronic system.
4. To choose programming technologies for developing the online assessment system.
5. To create a SQL database project based on determined system modules and to develop the system using the PHP programming language.

4. Research results

4.1. Defining requirements for software and e-system modules

The following list of requirements has been formed for the system of online assessment of students' academic achievements:

- Availability of educational courses that contain certain topics and lectures. For each topic, there is a set of control questions, tasks or tests. Tickets for exams are automatically created based on these control materials.
- The teacher can enter questions on the discipline into the database using a special input form, as well as upload lectures, laboratory work, guidelines, etc. The online system uses a parser to receive questions and tasks from these files and enters them into a database.
- Using the task generator, the teacher receives tickets with tasks. To do this, the generator receives information from the system database and in accordance with the configured parameters creates tickets with control questions. A ticket is a form with control tasks, designed for different types of control measures, such as tests, modular control tests, final certification.
- The student can view the content of the disciplines he is studying. For each discipline, which is located in the system, the applicant of higher education sees the scheduled exams, date and time of their holding. When the time to start the exam comes, the student receives a ticket with a specific task and can answer questions.

At the end of the time specified by the exam, the ticket with the student's answers is sent for verification to the online assessment system. If the ticket contains tests, the student and the teacher receive the result of the test immediately. If the ticket contains questions that require a detailed answer, it is sent to the teacher for re-view. After the test, the teacher gives an assessment.

In accordance with the above requirements, the main modules of which the information system should consist were defined. These are presented in figure 1 [25].

The "Catalog of academic disciplines" part of the system includes pages of the site, which displays a list of academic disciplines for the student, defined by his curriculum. Each discipline consists of a number of modules, these modules consist of a number of study topics, which in turn contain questions. The teacher inputs questions into the database himself using the form on the system page. The teacher can upload to the system such educational materials as lectures, practical works or a list of control questions. After this, the system automatically enters questions from these files into the database. In the future, these materials are used to generate tickets with questions or tasks for the test, credit test or exam.

The student can overview the files of lectures or other educational materials in the content of the discipline, as well as see the date when the exam will be held. During the exam, the student proceeds to the control tasks which he received in the ticket. A list of control questions for the student is not available until the beginning of the exam.

The "Generation of control tasks" part of the system includes the function of creating tickets with different types of tasks, in particular with questions that require an open answer, as well as tests with the choice of one or more correct answers. On the page with the list of disciplines, the

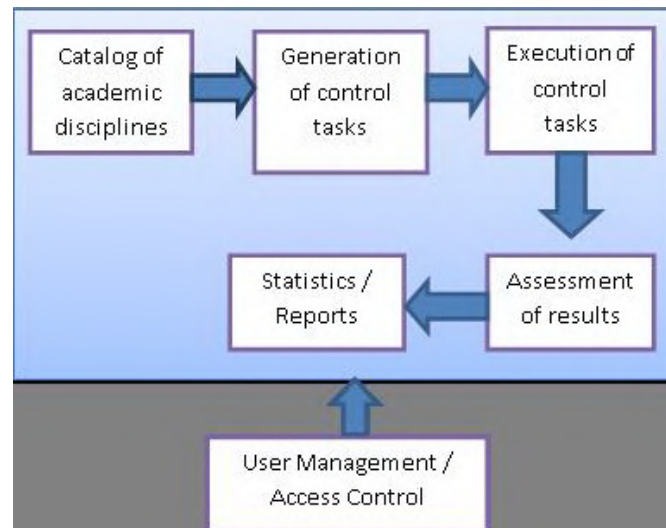


Figure 1: The modules of e-assessment system of students' knowledge.

teacher chooses academic discipline and moves to the page of the website containing educational subject topics. The function of creating an exam is available for the teacher. The ticket generator works according to the parameters specified by the teacher in the modal window of presets. The teacher sets the date and time of the test, chooses the type of exam (individual work, modular test, modular test or exam), sets the duration of the exam, specifies the number of test questions and points for the correct answer. After selecting the required parameters, the system generates the appropriate ticket with the task. The teacher can also add any question to the ticket and assess the answer.

The "Execution of control tasks" part of the system provides functionality to the process of passing the exam. The student with access to the exam, provided by the teacher, receives a ticket generated by the system and begins to pass the test. A list of different types of questions reveals. Upon accomplishing the ticket tasks, the completed form with answers is sent to the server, where the answers are processed. If the ticket contains only test questions, the system immediately provides a result on the correctness of the answers. If the ticket contains questions that require a written answer, the system sends a ticket with the answers to the teacher for verification. The sequence of actions for passing the exam within the information system of assessment is presented in figure 2.

The "Assessment of results" part of the system provides functionality to the process of checking the form of control passed by the student and providing results to the teacher and the student in the form of a PDF file. If the higher education applicant does not pass the exam, this feature will be unavailable and he will need to take the exam again. The student can review the questions, answers and analyze the result, seeing which questions were answered correctly or incorrectly. The teacher receives the results of the student's control measure in order to analyze the level of student achievement, to determine which topics need to be finalized. According to the results, the teacher assesses the exam.

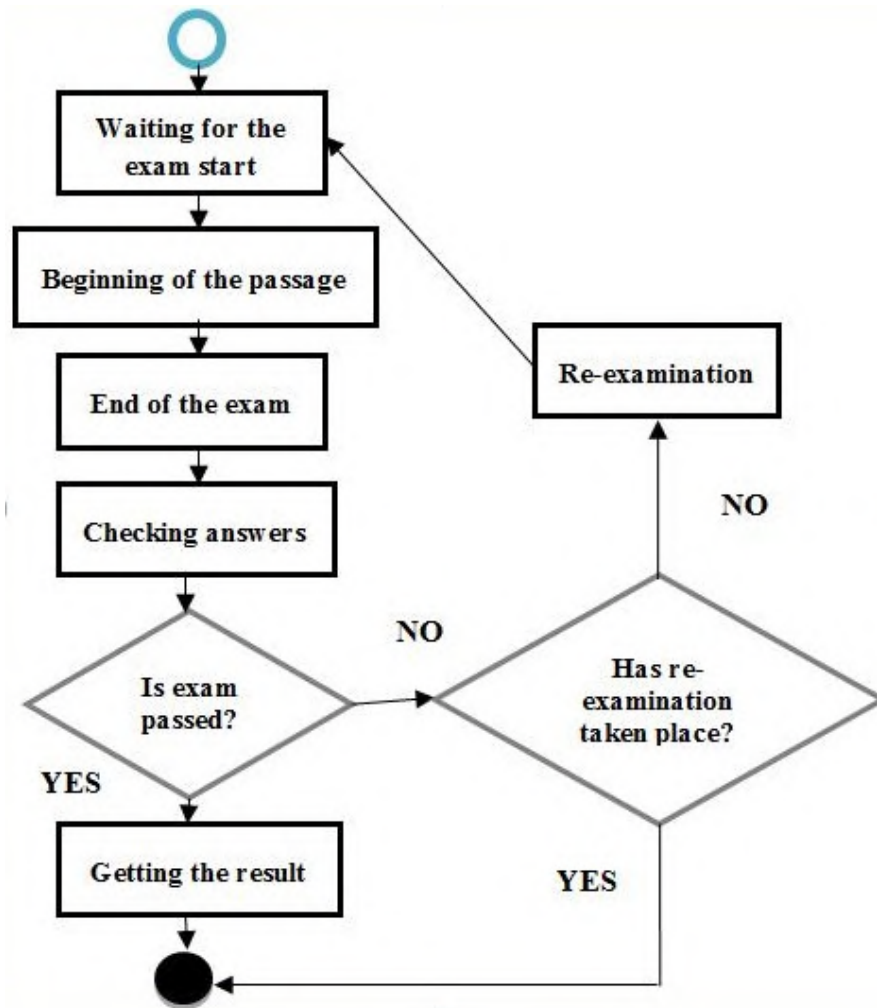


Figure 2: Diagram of actions of passing the exam by the student within the information assessment system.

In the “Statistics / Reports” part of the system, the processing of the general statistical information of educational achievements of the higher education applicant on disciplines takes place and also based on all points for educational disciplines the general rating of success of students is formed. The student has an opportunity to view a list of their subjects, current and final marks in the form of a record book.

The “User Management / Access Control” part of the system provides functionality to manage user rights. The features for each user are defined, as well as the level of access to certain data. A teacher can review his own academic disciplines, make changes to the uploaded files of educational materials, edit the points which are given to a certain student in discipline but cannot amend the disciplines of other teachers. The student cannot modify the content of their subjects or the results of assessing the levels of their academic achievements. The administrator can edit the roles of system users, make changes to the database, perform general system

management.

The sequence of actions in the proposed system is presented in figure 3.

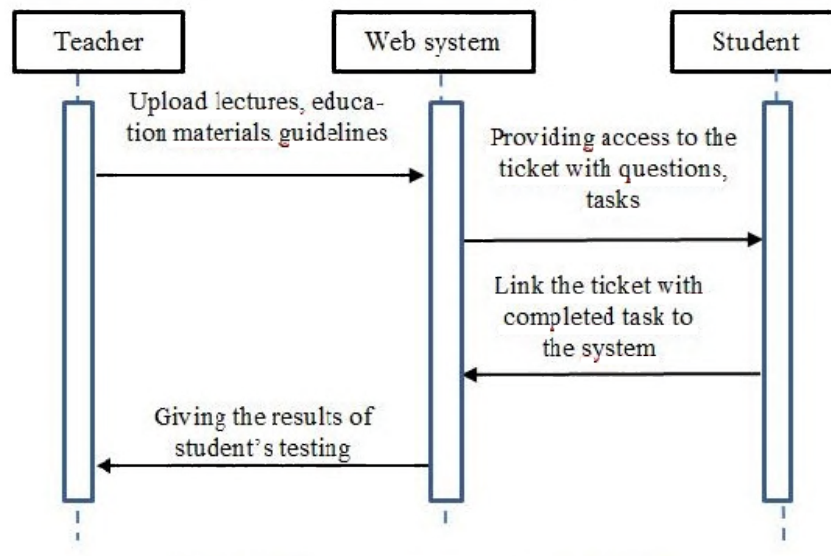


Figure 3: Sequence diagram of the e-assessment system.

4.2. Establishing roles and their functions in the assessment system

An electronic system for remote assessment created in the form of a web application is basically a website with the following functionality:

- registration of students and teachers;
- generation of tickets with control questions or tests from documents prepared by teachers and uploaded to this web resource;
- passing exams or other control measures within the higher education system;
- providing detailed results on passing the exam (test) by the student;
- formation of a students' rating based on assessments of levels of their knowledge on educational disciplines.

Within the developed e-assessment system, three roles were defined: system administrator, teacher and student. The roles of the system and their functions are shown in the form of a use-case UML diagram (figure 4).

The administrator in the electronic assessment system obtains the following functions:

- development and maintenance of a web resource, improvement and updating its current structure;
- technical support and security control of the website;

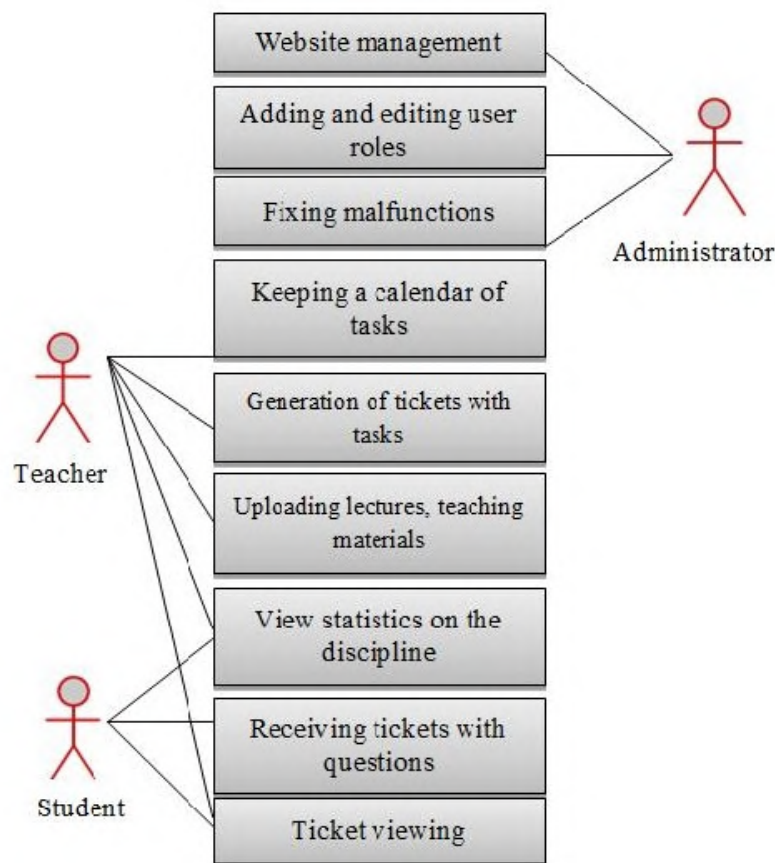


Figure 4: Users roles within e-assessment system and their functions.

- updating and editing the content of the site, order materials for the site through outsourcing, if necessary;
- feedback from the web resource users;
- control of the correct functioning of the site, tracking its availability for users on the network.

The teacher has the following functions within the e-assessment system:

- organization and support of the learning process;
- monitoring of the success training program completion in accordance with the curriculum;
- providing feedback to students;
- uploading of educational materials and tasks to the web resource in the form of tests or questions with detailed answers.

The student within the system of remote assessment has the opportunity to receive tickets with control tasks, execute the proposed tasks, and review statistical information on the discipline he/she is studying.

4.3. Choice of technologies for a software development

The choice of programming technologies for the developed assessment system was made due to some specialties: it will store information about students, teachers, files with educational materials, as well as user interaction with this information. At this stage of system development, you need to choose the technology for database management, the programming language to execute the logic and functionality of the program, as well as the technology for displaying this data. Also, a platform for testing the web resource is chosen.

The OpenServer software complex was chosen as the platform for developing and testing web applications [8]. The architecture of the location of the catalogs of the software complex implies a clear separation of two different types of data: variable user data (settings, temporary files, logs, etc.) and immutable service data (modules, programs, service files) [8]. In particular, the developed information system uses the following rules: in the modules folder the data never changes, here the standard libraries of the software complex, modules and settings are stored, and in the domains and user data folders, there is information that the software developer can change in accordance with website requirements and configuration.

In the process of developing an electronic assessment system, SQL technology was used for the MySQL database management system in the PhpMyAdmin web application. The Structured Query Language or SQL is a language for executing database queries, which is also used to manage and update databases [4].

The creation of the basic functionality for the e-assessment system was performed using the server-side programming language PHP. The main purpose of this programming language is to create scripts for web pages, as well as programming commands that run on server side. All operating systems, which support the web server maintenance, support PHP.

To build the structure of the website pages, HTML and the JavaScript programming language jQuery library were used, as well as the technology of accessing the server without reloading the page to update Ajax data, which is organized using JavaScript. Using Ajax helps us to avoid page reloading after each request sent to API, i.e. increases the system efficiency and improves overall user impression on interaction with the website [9].

PHPWord is a library written in pure PHP that provides a set of classes to write to and read from different document file formats. Using a software product such as PHPWord is required to read data from Word files.

MySQL technology was used to store system information and data. The language of structured queries is the standard language for executing queries, updating relational databases and managing them. SQL does not determine the sequence, but the result of some operations [4].

4.4. Development of the database structure of the e-assessment system

The structure of the database, designed during the creation of the remote assessment system and developed with the PhpMyAdmin environment using the MySQL data-base management system, is shown in figure 5.

Database tables of the developed electronic assessment system:

- Faculty-tb – a table with the names of the faculties of the higher education institution.
- Specialty-tb – a table with the names of the specialties of the faculty.

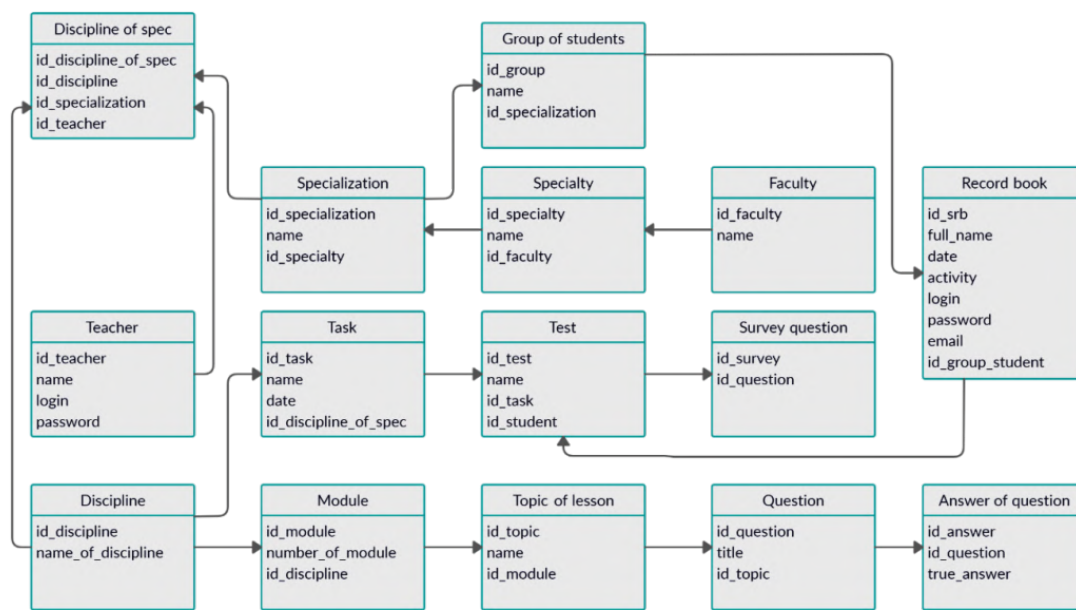


Figure 5: Users roles within e-assessment system and their functions.

- Specialization-tb – a table, which contains the names of specializations of the university.
- Group-of-students-tb – a table with numbers of students’ academic groups.
- Record-book-tb – a table with basic students’ data.
- Teacher-tb – a table with basic teachers’ data.
- Discipline-of-spec-tb – a table, which contains academic disciplines of the educational institution.
- Discipline-tb – a table with disciplines related to a particular specialization.
- Task-tb – a table, which contains control questions and tasks.
- Test-tb – a table containing tickets with questions and tasks.
- Survey-question-tb – a table with control tasks or questions related to a specific ticket.
- Module-tb – a table, which contains the ordinal numbers of the constituent educational materials of the disciplines.
- Topic-of-lesson-tb – a table with the topics of lecture materials.
- Question – a table that contains test questions for each lecture, practical work, case study or collection of educational materials.
- Answer-of-question – a table with the answers to the control questions are stored.

Thus, in accordance with the requirements for the application, a database was designed and developed for the electronic assessment system using PHPMyAdmin and the MySQL database management system.

4.5. Implementation of the electronic assessment system functionality

To use the electronic evaluation system and view its web pages, user must register and authorize. Registration is conducted for teachers and students. An email is sent to confirm registration for security purposes. After confirming the registration, a corresponding account is created.

After authorization, the student in the “Personal Profile” tab can see a table that contains information about his faculty, specialty, course, group and email. In the “Disciplines” tab, the student can see the list of disciplines and the average score in these subjects, which calculated of current points.

In the “Catalog of academic disciplines” module, depending on the user role, the teacher can see only his disciplines and the student has access to the disciplines, which are available in accordance with the curriculum.

In the “Generation of control tasks” module in the discipline, the teacher can create a control measure, such as an exam or test, plan the date and time of its conduct, select the training modules, which would be assessed during the control measure. The teacher specifies the required number of questions in the form of tests, points for the correct answers, number of questions which requiring a detailed answer. The created exam (figure 6) is inserted into the Task table.

Назва екзамену	Дата і час	Тривалість	Кількість запитань	Оцінка правильних відповідей	Статус	Запитання	Статистика
Test	27-10-2020 11:45:00	5 Хвилин	5 Запитань	1 Бал	В очікуванні	Додати питання	Результат

Figure 6: Page of the e-assessment system with the created exam.

The list of questions is retrieved from the Question table, to which the teacher can input questions manually or the system adds them automatically from the files of educational materials (lectures, practical work, etc.). Number of questions and tasks that require a detailed answer is defined in accordance with the parameters set in the settings menu. If there are not enough questions of a particular type in the database, the web system will create a ticket with the possibility for the teacher to add tasks to the ticket later. The ticket generator creates a ticket and inserts it into the Test-tb table, questions are inserted into the Survey-question-tb table.

The teacher can view the generated ticket, add or delete questions. The ticket created in the system is presented in figure 7.

In the “Task execution” module of the electronic assessment system, the higher education applicant gets access (previously provided by the teacher) to the exam at the time set when creating the exam and gets the opportunity to take a test, answering the ticket questions. The student studying a certain discipline receives a question from the table Survey-question-tb.

After answering the questions and taking the exam (or other tests), the student has the

Список экзаменів / Перелік питань

Перелік питань

Показати 10 результатів Пошук:

Назва питання	Правильна відповідь	Action
Що є програмування?	Відповідь	Редагувати Видалити
Текст питання	Відповідь	Редагувати Видалити
Текст питання	Правильна відповідь	Редагувати Видалити
Текст питання	Правильна відповідь	Редагувати Видалити
Текст питання	Правильна відповідь	Редагувати Видалити

Показано на сторінці 5 з 5 питань

[Попередня](#) **1** [Наступна](#)

Figure 7: Generated ticket with questions in the e-assessment system.

opportunity to download a PDF file that displays statistical information about the exam: question number, the text of the question or task, answer options, the option chosen by the applicant, the number of points for answers, as well as the final assessment for the exam.

The system sends questions that require a detailed answer as a form with answers after the exam to the teacher for verification. The rating of higher education applicants consists of the points they receive while determining the levels of their knowledge within a 100-point scale.

Thus, a system for assessing the levels of acquired knowledge of higher education applicants was developed, the interaction of modules which generate and process the information, with database tables, which contain that information aimed at assessing and monitoring students' academic achievements, was set up.

4.6. Approbation of the developed system for remote assessment of knowledge

The developed system for remote assessment of knowledge was used as part of the system for monitoring the levels of academic achievement of higher education applicants at Kherson State University for Master qualification level of "Software Engineering", "Computer Science", "Information Systems and Technologies" specialties. The electronic assessment system was used to control the level of acquired knowledge of students at full-time and part-time education forms in the total number of 39 people in the "IT Governance" discipline in 2019-2021 academic year at the Faculty of Computer Science, Physics and Mathematics of Kherson State University. Students were offered a final test in the "IT Governance", the tasks for which were generated by the proposed electronic assessment system, access to the system is presented on the KSUOnline distance learning platform of Kherson State University as part of the "IT Governance" distance course (figure 8).

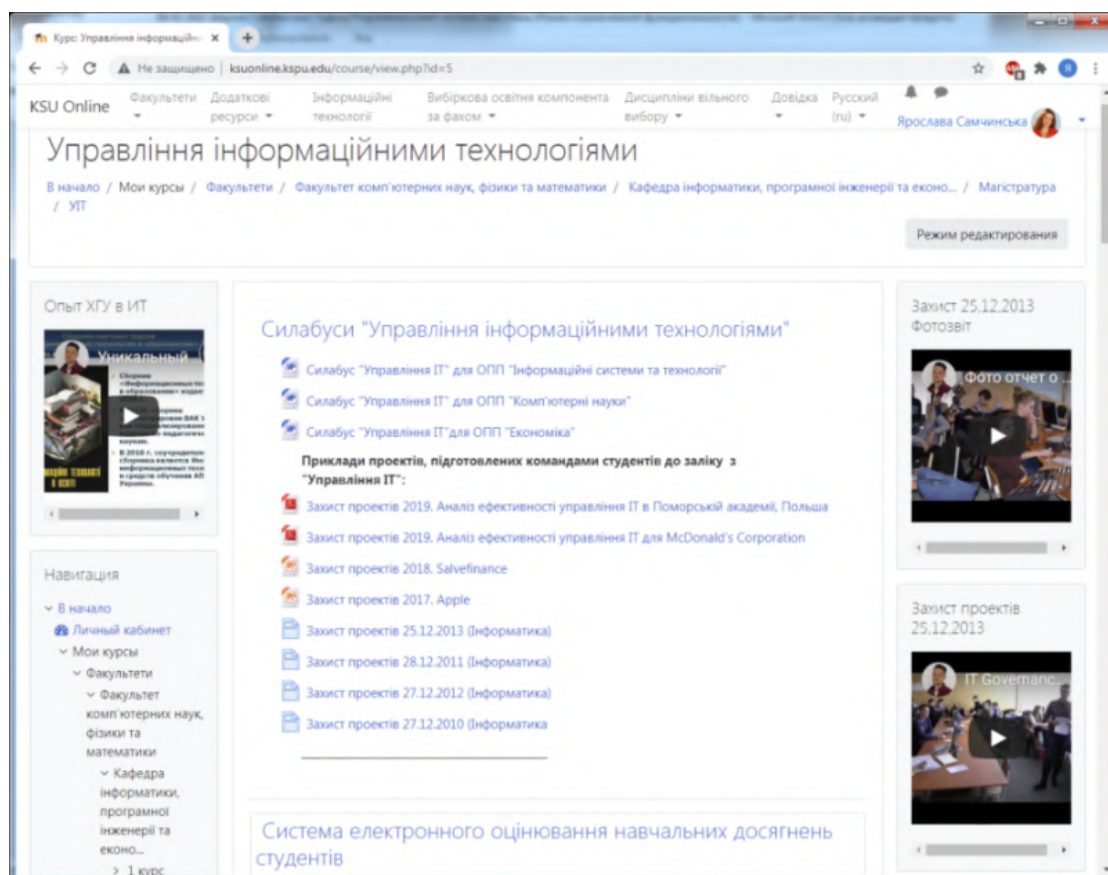


Figure 8: Using the electronic assessment system to control the knowledge of students as part of the “IT Governance” distance learning course in the KSUOnline of Kherson State University.

The usage of the proposed electronic assessment system of knowledge contributes to the formation of an open information and educational environment of a modern educational institution, enhances the efficiency and more rational distribution of teacher time in preparing tests or exams, activates repetition of educational material and knowledge assimilation, indirectly motivates them to more honest learning through the ability to compare their own academic achievements with similar indicators of other applicants for higher education.

5. Concluding remarks and future work

The conducted researches allow us to formulate certain results and to target directions of further developments in the field of higher education in the conditions of modern challenges. In particular, the expediency of development of the electronic system for assessment of students' knowledge was justified to ensure the efficiency and quality of learning, notably in the context of distance learning.

The system of remote monitoring of knowledge which automates the formation of tickets

with questions and tasks for conducting control measures, examinations is offered.

In the process of developing an electronic system for knowledge assessment, the basic requirements for a web application and the modules that the system consists of were determined, the main roles of users in the system and their functionality were identified, access rights were established. The technical, functional, and non-functional features of the software product are described, web technologies for creating an application for knowledge assessment are considered. The diagram of system sequences, the use-case diagram, which schematically describing roles and functions of agents in an information system, the diagram of classes of a database structure are presented with UML description.

Based on the defined requirements for the web resource, the following technologies for its development were chosen: the server programming language PHP, JavaScript programming language and its libraries were used, as well as the MySQL database with PhpMyAdmin tool for administration of chosen database management system. OpenServer software complex system was used to develop and test the application functionality.

The vector of further scientific development should be aimed at the formation of methodology and software for a common database for a group of higher education institutions on control tasks and tickets, which will provide greater objectivity, transparency and diversity of methods for assessing students' knowledge. Also, further research should focus on the integration of the electronic journal into the developed electronic system, which will allow forming a ranking of the success of higher education applicants.

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