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THE STUDENTS' KNOWLEDGE TESTING SYSTEM WITH GAMIFICATION ELEMENTS

Abstract. The described tools can be used to solve practical problems of ensuring the testing of knowledge of educational content provided to students studying in the specialty F2 "Software Engineering", using the appropriate educational information system. Tests on educational content are presented in the form of tables of the system database. The article considers the information system for testing student knowledge, which uses elements of gamification. The proposed system supports testing knowledge in the main academic disciplines of the specialty F2 and contributes to the process of optimizing data processing, which describes the process of testing knowledge. The educational components of the disciplines, from which knowledge testing is carried out, are organized in the form of a hierarchical model. The developed system for testing students' knowledge operates in the "student" (for testing student knowledge) and "administrator" (for forming test tasks) modes. The work examines in detail the "student" mode and the system database. Analysis of the results of the knowledge test determines the automation of the formation of an appropriate decision to determine the material that the student has not mastered at the required level. The use of a web system contributes to the process of automating the testing of student knowledge. The proposed approach to testing students' knowledge is advisable to use in the future for prototyping subject ontologies of academic disciplines of specialty F2.

Keywords: information educational system; information system for testing students' knowledge with gamification elements; educational content; testing student knowledge; hierarchical model; gamification elements.

INTRODUCTION

The development of information and intellectual technologies and learning technologies, the digitalization of various spheres of our life have contributed to a new view of online learning, in particular, learning to obtain knowledge and competencies in the field of programming and software development [3], [16], [18], [19].



Nowadays, there are many Internet learning and testing platforms that provide students with comfortable conditions for learning and testing knowledge.

To support (including psychological) students, increase their level of interest and motivation, it is advisable to introduce various approaches, methods and elements of gamification into the testing system, where the entire process of both learning and testing turns into an interesting game.

The development of a student testing system with elements of gamification is aimed at automating the testing process, reducing psychological stress and getting pleasure from the learning and testing process [2].

This approach to the process of testing students' knowledge provides, in particular [5]:

- increasing the efficiency of the work of system users (teachers, students);
- reducing the time required by the teacher to create tests and test tasks (for example, in the direction of learning F2 "Software Engineering") and receiving reports on the knowledge levels of the student, group, course;
- ensuring automation of all components of the student testing process;
- ensuring automation of all components of the student testing process automation of the process of processing data about the testing process.

GAMIFICATION IN EDUCATION

Gamification in education is:

- the use of game elements, such as levels, achievements, points, virtual awards, and others, to increase students' motivation and interest in learning;
- based on the theory of positive reinforcement, according to which desired behavior can be reinforced with positive consequences (for example, virtual awards for academic success) [4].

The advantages of gamification of learning and testing, in particular, are an increase in:

- student motivation to learn;
- the level of student involvement in learning and ensuring more effective learning of the material;
- increasing the competitiveness of existing online courses [4], [6], [9].

Gamification in education can be a useful tool for increasing motivation and effectiveness of learning. Its application may depend on the needs and characteristics of each specific group of students.

Gamification can help [7], [8]:

- involve students with different types of learning styles in learning;
- increase interest;
- motivation to learn.

However, gamification is not a universal solution and requires some training and effort from teachers and online course developers.

In addition, it is important to ensure a balance:

- to ensure a balance between gamification and traditional teaching methods, taking into account the needs and characteristics of students;
- to ensure the competent use of gamification to achieve maximum efficiency and effectiveness of learning [10], [11].

The concept of gamification is based on the use of various game elements, for example, such as [10,12,13]:

- scoring;
- competing with other participants in the educational process (other students).

Gamification can turn an ordinary task into an exciting, fun, educational, entertaining and interactive activity for each person.

It uses the natural desire of each person (and students are no exception) for:

- competition;
- achievements;
- communication using gamification elements (in particular, such as badges, leaderboards, stories).

When these elements are integrated into learning, they evoke an emotional response, creating a memorable experience that inspires students to work harder to master the relevant learning content and to test students accordingly, which contributes to improving learning outcomes.

Gamification is a powerful tool in the development of educational courses or tests to test students' knowledge, which:

- uses the appeal of educational games (or individual gamification elements);
- applies it to non-game contexts, such as education or training.

Gamification primarily involves the use of games (computer or board) or individual gamification elements



to increase student engagement and motivation to learn. However, the use of gamified learning does not mean that the entire learning process is transformed into a game.

It is more like bringing elements of an educational game (educational game design) to non-game environments, such as a learning environment.

Among the advantages of gamification, it is worth highlighting, in particular, such as:

- developing problem-solving skills;
- encouraging team spirit;
- learning from mistakes;
- expanding creative abilities.

THE USE OF GAMIFICATION IN THE PROCESS OF LEARNING AND TESTING STUDENTS' KNOWLEDGE

Let's consider a web-oriented testing system with gamification elements [5].

In our time, there is an increasing need:

- to increase the level of transparency and objectivity of student testing;
- individualization of learning processes.

For many students, a gamified approach to the learning process is more likely to keep their attention than traditional teaching methods, which makes gamification a powerful tool of modern education.

With the advent of information (intellectual) technologies, gamification tools have become more advanced and diverse, offering various ways to successfully use such elements as [17, 18, 19]:

- interactive quizzes;
- simulation educational games;
- educational programs with assessment systems (for example, in the form of prize points, cups for victory, etc.);
- educational programs using virtual reality.

Attractive aspects of games, in particular, are:

- intrigue;
- competition;
- achievement and satisfaction (from the educational game and, as a result, from learning).

Gamification tries to use these aspects, turning ordinary tasks into more exciting, interesting and fun, adding various game elements to them.

Educational games used in learning (testing) are conditioned by the provision of psychological needs of students for:

- competence;
- autonomy;
- connectedness with other students (according to the theory of self-determination).

But it should be noted that educational games also provide students with problems, overcoming which, students increase their own sense of competence and achievement. The ability to choose, which is provided to students, increases their sense of autonomy.

Multi-user educational games and puzzles contribute to a sense of connectedness with other students, creating a kind of community among students. The use of educational games can effectively motivate, becoming an important factor in student learning.

The system of obtaining points, awards, or achieving different levels creates intrinsic motivation in the student. The more he plays (or learns by playing), the better he masters the relevant educational content, and the more he receives all kinds of rewards.

What may initially be extrinsic motivation (the attractiveness of rewards, the number of points, the place on the leaderboard) gradually turns into intrinsic motivation (the desire to learn and become better).

Educational games also use the power of psychological influence when the student is fully immersed in the world of the educational game:

- achieving optimal performance;
- improving focus on learning;
- improving focus on mastering educational content;
- improving memorization of educational content;
- improving concentration when performing test tasks.

Tasks in educational games often require the use of problem-solving skills, strategic thinking, the use of memories and adaptability.



This “learning by doing” approach allows students to learn faster and retain information longer, because the knowledge gained during gamified learning is then applied in practice.

Ways to effectively integrate gamification elements into an online educational course, in particular, are [14, 15, 17]:

- defining clear learning objectives;
- using incentives (incentives can vary from points (“points”, badges) to leaderboards, progress bars or unlocking new content; awards should correspond to achievements, stimulating the mastery of educational content or testing);
- introduction of interactivity (active gamified learning or testing can be in the form of quizzes, tasks to distract attention, etc.);
- promotion of competition or cooperation (the use of elements of competition (leaderboards, ratings) or cooperation (team or group tasks) increases the interest and level of involvement of students in mastering educational content or completing tasks during testing);
- use of storytelling (narrative elements provide gamified learning or testing with an appropriate context, making it exciting and memorable);
- use of balance of complexity (the balance between the complexity and accessibility of mastering educational content or completing a test task);
- availability of feedback;
- the possibility of repeated attempts.

Adopting the described approach when developing an online course contributes to the formation of students' necessary qualities for effective learning and testing.

The use of gamification in this case is based on a combination of students' understanding of the knowledge of what motivates and attracts them, and the creation of an online course that transforms students' passion for games into significant learning outcomes (testing).

Learning strategies that will help when using gamification in learning (testing) [2, 5]:

- Formation of learning objectives, coordinating gamification elements with them.
- Choosing the right game mechanics that affect the level of effectiveness for students using: leaderboards, badges, “points”, scores, progress bars or competition among them or cooperation.
- Integration of feedback mechanisms (in gamified learning, feedback is implemented through points, scores, animated graphics, etc.).
- Balance of difficulty levels (an important element of an educational game is the balance between complexity (learning procedures, educational content, complexity and adequacy of test tasks) and students' ability to master the educational content or solve test tasks.
- Personalization of the experience (using adaptive learning trajectories, avatars or storytelling elements, etc.).
- Adding social gamification elements to learning/testing (leaderboards, team tasks, discussion forums).
- Testing and refining the online course.

Successful gamification is not only about the pleasure of learning. Such learning allows students to interact with the educational content.

DATABASE STRUCTURE OF THE STUDENTS' KNOWLEDGE TESTING SYSTEM WITH GAMIFICATION ELEMENTS

The infological model of the database of the student testing system based on the use of gamification elements provides for a description of:

- objects (concepts of the subject area) and the relationships between them;
- requirements for permissible data values that describe objects of the subject area under consideration, and for the relationships between these objects;
- subject area through the concepts:
 - entity;
 - relationships between entities;
 - properties (attributes) of these entities.

The following entities were used in the work:

- “User” – information about users (students, teachers);
- “Progress” – information about the progress of each student in learning;
- “Scope” – information about individual sub-areas of the field of study (for example, the area – “Programming language operators”), which the student must master within the online course, answer the



questions of the corresponding test in order to get the desired result after testing;

- "Topic" – information about individual topics that the student must study (for example, the topic – "Cycle operators of the C++ programming language");
- "Level" – information about the levels of complexity for each topic (educational content of the block, question, test, etc.);
- "Question" – information about the test questions;
- "Answer options" – information about the answer options for each test question;
- "Correct answer" – information about the correct answer for each test question;
- "Gamification element" – information about those gamification elements, which are used in the student testing system.

Attribute – a named characteristic of an entity [1, 2]. For example, "Level" might have the following attributes:

- low;
- medium;
- high.

Attributes are used to define what information should be collected about the entity.

The data base of the testing system with gamification elements contains the following tables:

1. The "User" table contains the following information:

- User_id.
- Surname.
- Name.
- Patronymic.
- Phone.
- Email.
- Specialization (for students).
- Group (for students).
- Course (for students).
- Login;
- Password/
- Role (teacher, student).

2. The "Progress" table contains:

- Progress_id – unique progress code;
- Level_id – level code.
- User_id – user code.
- Mark – grade.
- The "Topic" table contains.
- Theme_id – unique theme code.
- Name_t – theme name.
- Description_t – theme description.
- Module_id – module code.
- Weight_t – theme weight.

3. The "Level" table contains:

- Level_id – unique level code.
- Name_l – level name.
- Description_l – level description.
- Theme_id – theme code.
- Weight_l – level weight.

4. The "Questions" table contains:

- Question_id – unique question code.
- Question_text – question text.
- Level_id – level code.

5. The "Answer Options" table contains:

- Answer_option_id – unique code of the answer option.
- Answer_option_text – text of the answer option.



- Question_id – question code.
- 6. The "Correct Answer" table contains:
 - Right_answer_id – unique code of the correct answer.
 - Answer_option_id – code of the answer option.
 - Question_id – question code.
 - Relationship – relationship between two or more entities.

The following objects were selected in the system, which act as sections when creating testing blocks. These blocks were the development areas:

- "Code in C-like languages (C, C++, C#)".
- "Web-oriented code (JS)".
- "Web-oriented code on the server side (PHP)".
- "Databases (SQL, MySQL)".
- "Development of mobile applications (Java)".

For each of these topics, features were highlighted that are common to all areas and may have the same questions during testing, in particular, such as:

- Code file name extension().
- Function declaration syntax.
- Variable declaration syntax.
- Declaring variables of different types.
- Syntax for creating string variables.
- For loop structure.
- While loop structure.
- Function call.
- Passing function parameters.
- Creating a class.
- Class constructor syntax.
- Access modifiers in classes.
- Static class methods.
- Calling a static class method.
- Class object declaration.
- Class inheritance declaration syntax.
- Dictionary declaration as a data type

Thus, the development areas and groups of questions that will correspond to the subject areas were selected. To store all this data, a database was created in which these areas, topics and questions for the topics are stored.

To store the areas of the subject area, a table was created in which the area code and its name are stored.

The topics of the questions are stored in a table in which

- the unique topic code;
- the code of the area to which the topic belongs;
- the topic name, and its type are recorded.

All these tables allow you to store a tree, where at the first level there is a topic, at the second level there are topics and as letters, questions on the topic of the area.

The system must store the results of student testing, so two more tables were created:

- the user table contains the user code, his login and password;
- the user (student) testing results table contains:
 - testing code;
 - user code;
 - code of the area in which the testing was conducted;
 - number of points and testing time.

ARCHITECTURE OF THE STUDENTS' KNOWLEDGE TESTING SYSTEM WITH GAMIFICATION ELEMENTS

The developed system provides testing of knowledge of students studying programming (for example, in C, C++ or C# languages).

At first, the student does not strive to get the best results.



But when passing each block, his progress constantly increases.

This motivates the student to get the biggest reward (for example, giving all the correct answers;100% progress of execution; getting a higher score in less time).

To get all these rewards, the student must:

- train and remember which answers are correct for a particular question, so that when passing the test again, he can answer this question correctly;
- have the best result in the least time.

WORK IN THE "STUDENT" MODE IN THE STUDENTS' KNOWLEDGE TESTING SYSTEM WITH GAMIFICATION ELEMENTS

The student registers or logs in to the web-based knowledge testing system with gamification elements, after which he can start testing in one of the 5 academic disciplines. After the student selects the testing area, the system transfers him to the page where the testing takes place.

Questions in the corresponding area are provided to the student one by one.

After receiving answers to all questions, the system calculates points according to the number of correct answers to the topic and calculates the coefficient by which this topic is assigned. The points received by the student and the time spent completing the testing tasks are entered into the database.

Description of the student testing system with gamification elements

The system is based on a tree, where several paths depart from each development area, which refer to the topics subordinate to these areas and are their topics.

Each topic has several outputs that refer to the questions. Such a structure contributes to the scalability of the system to any tasks, adapting the areas, topics and questions to a specific question.

Each of the areas has sublevels that can be revealed, demonstrating all the topics of the questions that have been entered into the system.

An authorized student has access to taking the test.

After passing the section, the student's progress in completing the tasks is displayed on the main page.

This progress is the ratio of the sum of the points received for all tasks to the maximum possible number of them. The more tasks the student completes correctly, the greater the percentage of his overall progress (Figure 1).

In addition to the block that displays the overall progress, the percentage of how successfully the student completed the tests in comparison with others is also displayed.

In this case, the user has an average score for all tests higher than 69 percent of other users of the system.

The third block displays the average time to complete the tests in comparison with others. In this case, the user answers the tests on average one and a half minutes longer than others, which is displayed on the graph by marking the red zone to the right.

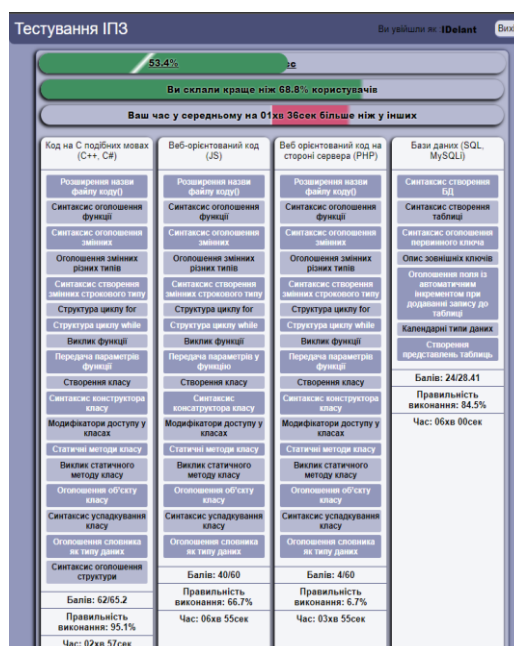


Figure 1. Main page when a student completes testing from most blocks

If the user answers faster, he will be given a feedback message, as in Figure 2.

The tasks page displays a block that displays the name of the area, topic, and current question for the task.

The parts responsible for gamification are presented in the form of testing time and the number of tasks already completed.

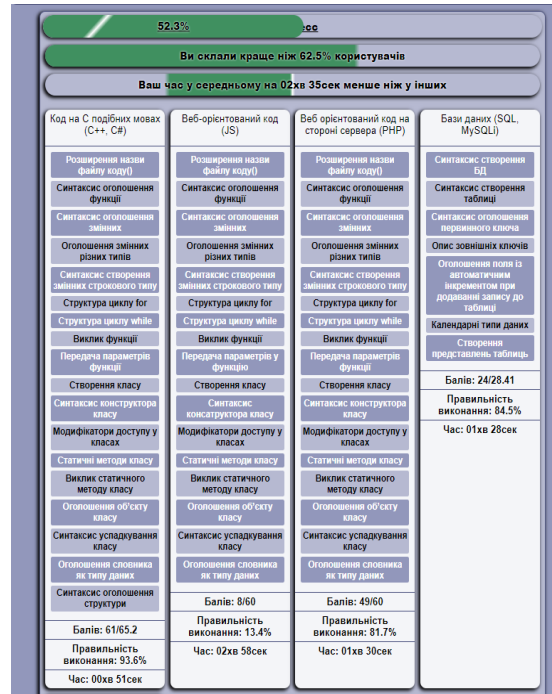


Figure 2. A time graph view, if the user is faster than others on average

In addition, when answering questions, new elements appear that encourage the student to complete tasks faster and more correctly.

These elements are a display of the correctness of filling in the corresponding fields and a notification to the student of questions (tasks), the testing of which depends on the correctness of completing individual tasks. The student is given an appropriate message.

If he answers correctly, then an encouraging text is displayed to him. In cases of a negative result, messages of other categories will be displayed to the student: "completely correct answer", "partially correct answer" or "practically incorrect".

In addition to messages, the student also has the answers "highlighted" in color: correct ones are green, incorrect ones are red. In addition, a short audio file is played, signaling the student about the correctness or incorrectness of the answer. This helps him understand in which blocks the answers were incorrect.

The sound reinforces the student's desire to answer correctly. Interface elements that are displayed during testing:

- time that has passed since the start of testing in the format "minutes: seconds";
- name of the general testing area;
- number of the current question and total number of questions;
- category of the question, which is also displayed on the main page under each area;
- name of the question to be answered – field for entering the answer, which already has a partial answer, and only needs to partially fill in the missing parts;
- button for confirming the question.

The main element that needs explanation here is the field for entering the answer. It consists of fixed text that the user cannot edit, and a field for entering part of the answer.

After completing the test, the user can return to the main page. Description of work with the system for administrators of the student testing system.

The main task of administrators in the knowledge testing system with gamification elements is to add appropriate educational (in particular, test) content to the system pages.

To do this, administrators have tools at their disposal, in particular, for:

- creating blocks of educational (test) content;



- editing the content of blocks of educational (test) content;
- deleting various blocks of educational (test) content.

To log in to the administrator page, you need to:

- log in using their credentials;
- click on the phrase "You are logged in as:".

Clicking on this link will take the user to the administrator page. This page has a navigation bar at the top, through which the administrator can navigate between other administrative pages, which are the main page, with content editing, a page with student testing results, and a page with adding and removing administrators.

The first page presented displays blocks that are drop-down lists.

The first block from each list is always a block for adding a new element to the list, in this case, a topic, that is, adding to the highest level of this list, which is the development area.

To add a new area, you need to enter its name in the "Topic name" field and click "Add topic".

After clicking, the system will notify the user about the result of the request to the server, which may respond that the add command was executed with an error and there is no connection to the server.

Since the testing is based on the fact that the student enters the correct parts of the code into the already partially written code, based on the question, in order to enter the answer that will be displayed to the student, you need to specify which parts of the answer will be hidden and will require input from the student. For this, special formatting was created, which looks like: "<USIP></USIP>".

Between these tags, the answer to the part of the code that will be hidden from the user is entered.

To create a correct question, it is better to put each keyword of the code in separate blocks, and leave some blocks visible to the user, as in this case, the word "class" and "{}" were not hidden so that the user could navigate which parts of the code need to be inserted into the blocks for input.

You do not need to insert these tags every time, you just need to press **ctrl+U** or **ctrl+G** to automatically create this tag. The second page of the administrator is "Results".

This page displays students registered in the system. Students who have their own list of testing tasks that they have already completed and the points received for them and the time for completion have already been calculated. Thus, the administrator can see the number of points of each student and the time it took for each test.

CONCLUSIONS

This article analyzes existing approaches to developing web-based systems, specifically testing systems with gamification elements.

The developed web-based system, using gamification elements for assessing the knowledge of students studying in the F2 "Software Engineering" specialty, helps solve a number of problems, including:

- automating the process of testing student knowledge;
- automating the processing of data representing the test results of an individual student, a group, or an entire course;
- improving the efficiency of training and testing processes;
- increasing the objectivity of the testing process by using an "independent, objective" tester of student knowledge, which is the system;
- automating the generation of relevant reports on student testing results;
- automating the process of generating relevant decisions about the students' achieved levels of knowledge, skills, and competencies in programming and software engineering.

The system uses a model of the fundamental components of learning, where each area of software development contains several topics subordinate to these areas and, as constituent components, their components. Each topic, in turn, has several blocks of test questions (test assignments).

The hierarchical model used allows the student knowledge assessment system to be scalable to any subject area or any assignment, adapting areas, topics, and questions to a specific section (topic or block of topics).

The developed knowledge assessment system will help students in the F2 "Software Engineering" specialty with varying levels of knowledge, skills, and competencies receive a personalized and adapted approach to learning, making the learning and testing process more effective.

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СИСТЕМА ТЕСТУВАННЯ ЗНАТЬ СТУДЕНТІВ ІЗ ЕЛЕМЕНТАМИ ГЕЙМІФІКАЦІЇ

Анотація. Описані інструменти можуть бути використані для розв'язання практичних завдань забезпечення тестування знань навчального контенту, що надається студентам, які навчаються за спеціальністю F2 «Інженерія програмного забезпечення», із використанням відповідної освітньої інформаційної системи. Тести з навчального контенту представлені у вигляді таблиць бази даних системи. У статті розглянуто інформаційну систему тестування знань студентів, що використовує елементи гейміфікації. Запропонована система підтримує тестування знань з основних навчальних дисциплін спеціальності F2 та сприяє оптимізації процесів обробки даних, що описують процес тестування знань. Освітні компоненти дисциплін, з яких здійснюється тестування знань, організовані у вигляді ієрархічної моделі. Розроблена система тестування знань студентів функціонує в режимах «студент» (для перевірки знань) і «адміністратор» (для формування тестових завдань). У роботі детально розглянуто режим «студент» та базу даних системи. Аналіз результатів тестування знань забезпечує автоматизацію формування відповідного рішення щодо визначення матеріалу, який студент не засвоїв на належному рівні. Використання вебсистеми сприяє автоматизації процесу тестування знань студентів. Запропонований підхід до тестування знань студентів доцільно використовувати в подальшому для прототипування предметних онтологій навчальних дисциплін спеціальності F2.

Ключові слова: інформаційна освітня система; інформаційна система тестування знань студентів із елементами гейміфікації; навчальний контент; тестування знань студентів; ієрархічна модель; елементи гейміфікації.

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