

# Dynamic Information and Analytical System for Assessing and Managing Acquired Knowledge

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**ABSTRACT.** The paper presents the concept of a system for the intellectual digital e-university of the future (IDEUF) based on an integrated database that ensures the correct function of the whole university system. Particular attention is paid to the process of checking students' required and current level of acquired knowledge, which is considered one of the main parts of the educational process. The article provides a detailed comparative analysis of actual testing systems and presents a proper testing system model within the IDEUF framework. The proposed system considers the testing principles, scales, and technologies for test building and preparing educational materials

**KEYWORDS:** testing systems, digital education, educational materials, database

## SISTEMA DINÁMICO DE INFORMACIÓN Y ANÁLISIS PARA LA EVALUACIÓN Y GESTIÓN DEL CONOCIMIENTO ADQUIRIDO

RESUMEN. El artículo presenta el concepto del sistema de e-universidad digital intelectual del futuro (IDEUF, por sus siglas en inglés) fundado en una base de datos integrada que asegure el correcto funcionamiento de todo el sistema universitario. Se presta especial atención al proceso de verificación del nivel requerido y real del conocimiento adquirido por los estudiantes, que se considera una de las partes principales del proceso educativo. El artículo proporciona un análisis comparativo detallado de los sistemas de prueba reales y presenta un modelo de sistema de prueba adecuado dentro del marco de la IDEUF. El sistema propuesto considera los principios de evaluación, escalas y tecnologías para la formación de pruebas y para la preparación de materiales educativos.

PALABRAS CLAVE: sistemas de prueba, educación digital, materiales educativos, base de datos

## 1. INTRODUCTION

Nowadays, we live in the age of digitalization, when many business processes, and not only, are being moved into online environments, and new processes are also being formed. Digital education has been developing exponentially in the last few years, especially due to contemporary realities, such as the COVID-19 pandemic. All types of digital tools for education, including test systems, now constitute an integral part of our everyday routine and should be perceived not as a tribute to fashion but as a necessity for younger generations that are often called “digital natives” (Małkosa, 2013).

The term “digital technologies” is used in this research for the widest variety of software and hardware tools, including information communication technologies. The term “digital education” describes the wide range of educational processes that involve digital technologies (Blundell et al., 2016). Implementing digital technologies in education is a mechanism of educational reform introduced by means of a transformation of teaching practices. Although it is a mighty intermediary instrument, the Internet should not be perceived as the ruling master of modern education; instead, schools and universities set goals and identify the ways to achieve them with help from a variety of digital tools, like computer testing or e-course books (Małkosa, 2013). Multimedia study environments are more flexible, get students more involved in the educational process, give access to a great variety of informational sources, including teaching materials and opportunities to develop professionally, and so improve the effectiveness of the process, help minimize the pressure on teachers and raise the overall level of education. The researchers supporting online education worldwide underline that it helps to prepare students for future professional activities and working realities as well as to provide opportunities to bring high-quality education to the most remote areas (educational equity) (Best & Dunlap, 2012; Małkosa, 2013).

Online education requires the following conditions: high-speed Internet connection, a variety of devices (laptops, tablets, one-to-one computing environments, etcetera), online and/or blended classes, software for personalized learning, learning management systems to gather and track data, provide a platform for online institutions, personalize content, maintain administrative records, etcetera (Best & Dunlap, 2012).

Unfortunately, the full potential of digital education has yet to be realized, which presents an attractive field for a broad spectrum of researchers. Students do not demonstrate progress just using e-books instead of their paper copies. That is why it is necessary to improve the systems of online education. The requirements for specialists are changing, new professions are emerging, and the established standards of the educational process as a whole are constantly being revised. As a result, digital instruments should be improved, and there is also a vital need for a “modernized” university capable of solving a number of new tasks that remain unsolved by the classical university.

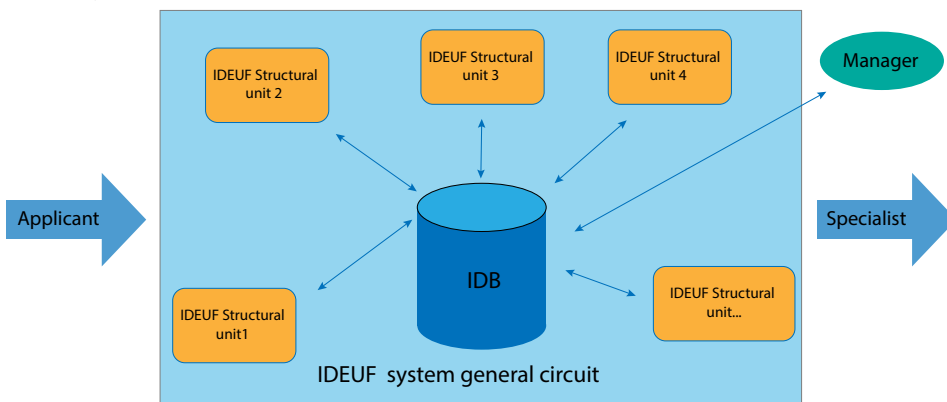
A university is an organization for the acquisition (transfer) of knowledge. A modern university should be an integral system, with an applicant as input and a specialist as output. Applicants' knowledge at the start of the process and specialists' at its end correspond to standards projected within the system and may change due to current requirements and realities. The system is an integral unit, which includes interacting, closely interconnected structures that ensure the correct working of the system.

The educational process, university infrastructure, scientific and methodological activities, housing stock (dormitories), student leisure, etcetera are university structures that are functionally and structurally different but ensure the unity of the university system and its ability to fulfill its educational task. The unity of these structures should be ensured by an integrated environment and an integrated knowledge base. The latter provides a timely, rapid exchange of knowledge, which is updated and accumulated in a prompt manner and creates a basis by which to manage the system, considering the needs of all its structural components.

## 2. MANAGEMENT OF THE INTELLECTUAL DIGITAL E-UNIVERSITY OF THE FUTURE (IDEUF) SYSTEM

The intellectual digital e-university of the future system includes an integrated database (IDB) and all other directly interconnected components of the university system. This approach allows to manage the entire system more effectively and to set up the main process of the system, the students' education, and other vital processes for the system in an efficient manner. The work of all components, including feedback, continuous and well-timed interaction of components, and timely data exchange, is provided by an IDB. It acts not only as a data exchange center for the system but also as a center for knowledge/experience accumulation. Accumulated knowledge can be used to make further management decisions regarding the university system.

**Figure 1**  
*IDEUF system*



### 3. COMPARATIVE ANALYSIS OF TESTING SYSTEMS

This part of our research focuses on computer testing systems. Evaluative testing of students' knowledge is one of the fundamental elements of the educational process. The effectiveness of this process is closely related to the development of methods for knowledge control. Achievements in education sciences highlight the successful use of tests with the help of computer systems, for example, during the experimental implementation of the Unified State Exam in Russia. The variety of systems we will analyze can be applied to different levels of education, from elementary school to university. Checking the compliance of knowledge with specified standards with the help of a testing system is one of the most important processes in the university system, which is being designed in response to the great demand for innovations in control systems for students' knowledge and skills. Computer testing is considered the universal method of control and evaluation in the educational process. It also helps to individualize learning and provides students with opportunities to organize self-training, as well as to increase students' and teachers' productivity by reducing the time spent on checking drastically. With the help of testing systems, it is possible to create a large bank of tasks with high evaluation objectivity. Providing equal objective conditions for all students requires the correct control questions that guarantee the right answer is unambiguously distinguished from the wrong one. In addition, the testing results should be easily identifiable.

A comparative analysis of the most common systems in the educational field is necessary because there is a great variety of testing systems and software complexes on the market. All of them have the common function of providing control both locally and remotely.

Table 1 lists 10 testing systems with their main characteristics.

**Table 1**

*Testing system comparative tables*

N.º	Name of the system	Type	Characteristics
1.	Apolo	Cloud-hosted version	There are no built-in analytics, only the number of correct answers is visible. The user is displayed as an email address in the system. There is no error checking (it is possible to create a question where all the answers are incorrect, and none of them has a tick mark for the correct answer). Test notifications arrive by mail from the Apolo team, and not from the structure, that uses this system for testing. There is a timer for the whole test, but no timer for single questions. It is possible to create questions with single and multiple-choice answers (Tirthankar, 2021).

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2.	SunRav Web Class	Box version	Platform for storing ready-made tests. To create tasks, tMaker constructor is also needed. In the system, it is possible to create two types of tasks: "true – false", "put a score from 1 to 10". tMaker program helps to expand this list to seven: single and multiple choice questions, match, ordered lists, questions with an open line to write an answer. There are four report types: Answer Matrix, User Outcomes, Group Reports, and Topic Reports. The report format is csv. (Vereshchagina & Shaker, 2009; LmsList.ru Distance Learning Systems, 2019).
3.	ISpring	Cloud-hosted version	Platform for online learning and testing. There are 14 types of tasks: matching, single or multiple choice, area selection, drag-and-drop, sequence etcetera. It is possible to change the design of each question and set the rules for the test: set points and penalties, mix tasks automatically before testing, specify the number of attempts and limit the response time for each question, so that students do not cheat. You can carry out tests using computer or mobile phone. There are 15 report types available. The system collects all information (answers, time) into reports that can be downloaded in excel format (Zaripova N. & Zaripova M., 2014).
4.	StartExam	Cloud-hosted version	There are analysts that check the answers and collect reports. In the test, you can set time limits for tasks and for the number of attempts and mix the questions automatically before starting the test. You can create polls and quizzes using 9 types of questions: single and multiple choice, sorting, matching, text input, essay, Likert scale, video interview and 360-degree assessment. In addition to questions, information slides can be added to the test. If a student makes a mistake, StartExam will automatically send him to this slide. The StartExam report has 29 fields by default, it is possible to select certain options and turn off the extra ones (LmsList.ru Distance Learning Systems, 2019).
5.	Indigo	Both cloud-hosted and box versions	Professional tool for testing and processing results, designed to solve different ranges of tasks: knowledge testing and control of knowledge level of students, psychological testing, surveys and competitions. The demo version is available on the official website, where a licensed copy can be purchased. There are three types of tests: a survey, a knowledge test and a training test. The latter shows the correct answers if the student makes a mistake. Test Builder offers to create five types of tasks: single and multiple choice, answer entry, ordering and matching. The number of questions is unlimited. It is possible to set time limits for each task and add explanations and tips. It is also possible to import questions of all types from text files (.txt), work simultaneously in the editor with several tests and copy questions and groups of questions from one test to another. The program will automatically send a link to the finished test by mail to every specified student. Statistics: the system shows the points or percentages the students scored and the mistakes they made in the test. Reports in XLS format. The system stores information about users and can provide information about the tests carried out by users. The program has an intuitive and modern interface. It is possible to divide users into groups and send them e-mails, as well as import and export user lists to transfer information to another device. Among the disadvantages of the system are the price and the size of the program that reaches 125 MB (without tests) (Glazov & Emelyanova, 2016; LmsList.ru Distance Learning Systems, 2019).

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6.	TestMaker	Box version	Local software system for testing with an unlimited number of questions and answers. It allows the creation of sets of tests for monitoring students' knowledge, and it is possible to change previously created tests, display test results in percent, save test results in text/encrypted format, save newly created or modified sets of tests in a self-executable file. There is no possibility to build reports on the results of testing. also It is possible to create different types of questions, add graphics, images, formulas, time limits, and generate questions randomly. During the test, students see the time spent and the number of the tasks completed. There is no possibility to view the theoretical part before passing the test. The software works on Windows 2000/XP/Vista/Server 2003/Server 2008/7, and the interface is intuitive and modern (Matveeva & Frolova, 2016; Ilyina et al., 2017).
7.	Examiner	Cloud-hosted version	Program for exams, digital and "paper" testing, for educational institutions and any subject studied. It enables the use of text or graphics for questions. The number of tests and questions in tests is unlimited. The system provides separate roles for teachers and students. Both parts of the program can be installed on the same device or on different devices on the local network. Users have to log in to run the teachers' program. Within the program it is possible to create courses and link various tests, so students can choose courses and disciplines before going to the page of tests available for each selected course. There are only two types of questions, single and multiple choice. The software package provides an opportunity to display the time spent on the test and a preliminary assessment. The system allows to set a minimum percentage for successful test pass, skipping questions and moving on to the next blocks. Tasks for tests may be issued out of order (Matveeva & Frolova, 2016).
8.	RichTest	Box version	Software package for creating test tasks and conduct testing. It consists of three modules: Admin (designed for creating and editing test tasks), Customer (designed for testing), and Reports (designed for collecting and analyzing test results in the form of reports). The system complex allows to pass to the theory before the test and to the training mode, where the correct answer is displayed in case of an error. The test settings are very flexible, which allows the creation of various types of questions, tips and answers, but not questions of extended answer type or more complex tests with different correct values. It is also possible to set the level of difficulty for each question, to build reports on test results with detailed information about mistakes, hints, etc. Technical support is available as well (Alyautdinova et al., 2017).
9.	UniTest System	Both cloud-hosted and box versions	Powerful product for automation of the testing process. Using UniTest System, you can create your tests using text, graphic editor or specialized programs (for example, AutoCAD). Functionality of the UniTest System software package includes the ability to use any OLE objects in your questions. In each question, you can set a number of correct and/or partially correct answers. There are six types of tasks: multiple choice, unordered choice, ordered choice, match, direct input. Subtexts allow you to highlight sections in the test and build a database of questions. The UniTest System has a rather complex interface, so basic skills are required to work with it (Shakhov & Demkin, 2017).

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10.	VeralTestEditor	Both cloud-hosted and box versions	Software package that provides testing or certification for students. The main advantage is the interface simplicity that allows for the creation of single .exe tests, which can be run on any personal computer on Windows without installing additional software. There are different types of questions available, such as single and multiple-choice questions, text and number input questions, match (order elements or group any elements according to certain characteristics), as well as opportunities to prepare "paper tests" to use during offline or blended classes. It is possible to import questions from a file and to insert pictures and resize them without help of other programs. The program has an intuitive and modern interface, and technical support is available. All necessary documentation is available in the program (menu item "Help – Contents") (Ilyina et al., 2017).
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1. Judging from Table 1, none of the presented systems can be used to implement the IDEUF system, since this system requires a combination of the following solutions:
  1. Direct binding of the test question to the materials used
  2. Possibility to sort users into groups and to assign tests immediately to user groups
  3. Possibility to quote a period when every particular test is available (for example, access from 00:00 March 1 to 00:00 March 7)
  4. Possibility to set time limits not only for the tests, but for individual questions as well
  5. Possibility to create tasks (questions) of various types
  6. Automatic task checking for questions with open answers
  7. Statistics for a certain period both for user groups as well as for single users
  8. Binding questions to educational materials and the possibility to create recommendations automatically
  9. Possibility to create different variations of tests by mixing lists of questions

Due to the fact that none of the present systems meets the entire range of requirements, a decision was taken to create a new system for knowledge assessment.

#### 4. TESTING PRINCIPLE

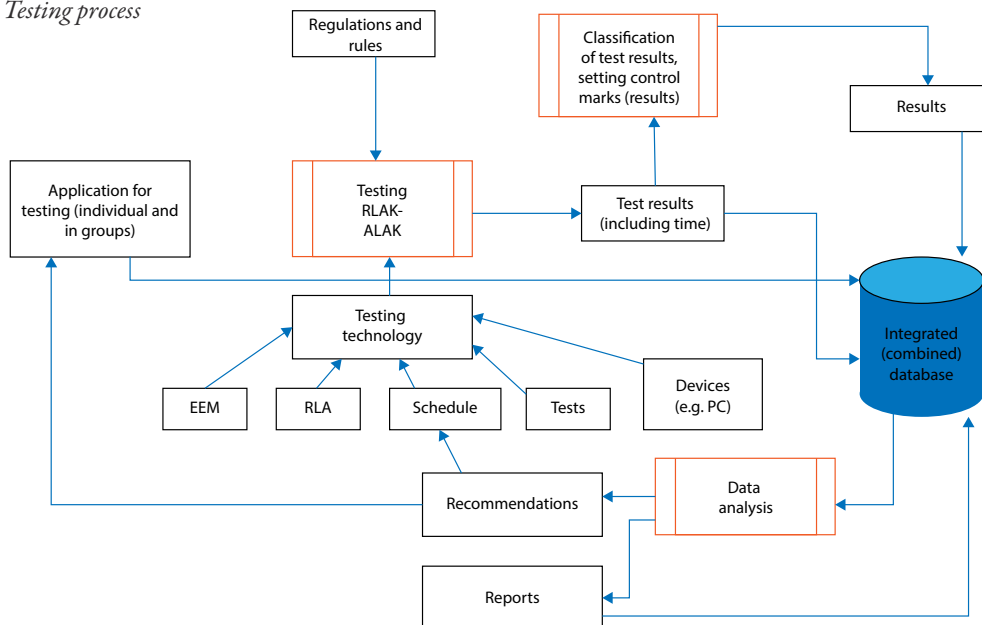
Our work is based on the testing process adapted from the principle of 3-component testing, which is described in Dobrynin et al. (2022a, 2022b). To quantify the final knowledge (FK), the function (F) of understanding (U), skill (S) and proficiency (P) is used.



$$FK=F(U, S, P) \quad (1)$$

The testing process starts with a testing request, which enters the input of the RLAK-ALAK testing process. The test results are sent to the integrated database to be analyzed (see Figure 2). Based on the analysis, reports and recommendations are generated, which are also recorded in the Database and can become the basis for adjustments to other processes and components of the IDEUF (for example, EEM, schedule).

**Figure 2**  
*Testing process*



*Note.* Required level of acquired knowledge (RLAK); actual level of acquired knowledge (ALAK); electronic educational materials (EEM).

## 5. THE PROCESS OF PREPARING AND EDITING EDUCATIONAL MATERIALS

The testing process is based on educational materials widely used in the learning process, that is why, in this part of our research, the process of preparing electronic educational materials (EEM) and the relationship between the processes of EEM preparing and testing are considered. In the process of preparing and editing educational materials, an electronic version of the EEM is formed, which is formatted according to a certain technology during the loading of the EEM into the system. The formatting of educational materials is based on the idea of

scientific texts analysis (Filozova & Dobrynin, 2012; Dobrynin & Filozova, 2014, 2015). Educational materials are divided into the following sections:

- Basic attributes (separate parts) of a scientific text (title, information about authors, abstract, keywords, main text, bibliographic references, bibliographic list)
- Key words (used to compile a glossary of terms)
- Questions to various parts of the main EEM (questions are allocated to each semantic part, the answer to which is contained in the corresponding passage of EEM)

### Questions to EEM

A logical-semantic network “question-answer” is being formed. Educational materials are prepared in a specific way for further use in the system. EM are divided into topics, a list of questions is compiled for each topic, direct links are formed between the questions and the paragraphs of each topic considering this or that issue (see Table 2). This division allows the building of individual learning paths: to choose questions of interest and study only those parts of the topic that correspond to the selected questions. In the educational materials, the main terms are highlighted, a list of keywords and phrases of the topic is compiled, which can be used to compile tests and check the test results.

**Table 2**

*Example of EEM division*

Topic text divided into semantic parts	Question numbers corresponding to the topic of the paragraph(s)
Digital energy, including smart instrumentation systems...	1,3,7
Digital products: including cloud and infrastructure products based on the development of proper processing centers...	2,4,5,9
Digital NPP, including: Digital NPP project; Digital operating template...	6,8,10

### Schedule

Schedule is another important component in EEM preparation. The schedule is directly related to EEM, at least in parts. The schedule indicates the dates and times when a certain part of EEM is opened (including tests), the deadlines for completing the tasks and sending them for control, as well as a timetable of online meetings for a single student (or group of students) with a teacher or more (see Table 3).

**Table 3***EM schedule for a discipline*

EEM	Dates and times (when the access to EEM is granted and blocked)
Topic 1: Studying experience of successful management of global corporations allowed the author to conclude that to improve the efficiency of...	01.09.2022 (00:00) – 31.07.2022 (00:00)
Topic 2: After studying the world experience, the author identified the following main models of knowledge management in corporations...	
Task 1: Draw a diagram...	01.09.2022 (10:00) – 10.09.2022 (00:00)
Task 2: Make a plan...	
Lecture 1	01.09.2022 (09:00) – 01.09.2022 (10:40)
Seminar 1	01.09.2022 (10:40) – 01.09.2022 (12:20)
Test 1	:00) – 30.09.2022 (00:00)

## 6. CONCLUSION

University should be a well-coordinated unified system. One of the main processes in university is the learning process and the related testing process. To achieve greater transparency while testing knowledge acquired by students for a certain period, we proposed a system which linked the educational material directly to the test questions. One of the main advantages of this system is that this approach alleviates teacher stress. With this system, routine work disappears. The material to be studied doesn't have to be specified in order to answer the test questions correctly; recommendations are formed automatically and require only one-time filling. Moreover, this approach is suitable for use in the IDEUF system.

Despite all the advantages of this approach, there are some limitations. This system is designed for computer testing, i.e. in electronic form. Another important condition and limitation is that the material must be submitted in electronic form and processed (classified) into certain groups before the educational process starts for further linking to the test questions.

In the following works, we are planning to develop the system that forms and links educational materials to test questions. The main feature of the testing process is the use of 3-component testing of the final knowledge. What is more, in the following works we are planning to discuss the relationship and possible modification of other components of the university system.

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