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INFORMATION TECHNOLOGY OF THE ACQUIRING PROFESSIONAL COMPETENCIES PROCESS IN THE E-LEARNING MANAGEMENT SYSTEM ENVIRONMENT BY CONSTRUCTION AN EDUCATIONAL TRAJECTORY

Abstract. The **subject matter** of the article is the construction of an educational trajectory in the environment of an electronic learning management system (ELMS). The **goal** of the study is the development of information technology ensures the effective use of web-resources in technical disciplines at a university for the acquisition of professional competencies in modern conditions. **The tasks** to be solved are: to organize the web environment in the e-learning management system (ELMS) for studying the discipline in a technical university on the principles of information technology; to construct an educational trajectory for the acquisition of professional competencies in technical disciplines at a university according to Bloom's taxonomy; to search ways to optimize the processing of information on web resources using the mathematical apparatus of graph theory; to develop of a recommendation on the construction of an educational trajectory for the professional competences acquisition. General scientific and special **methods** of scientific knowledge are used. The following **results** were obtained: The process of acquiring professional competences in the web-environment of the e-learning methodological complex is presented in the structure of information technology. Based on the functional distribution of teaching aids, a flowchart of the e-learning methodological complex and an algorithm for achieving the formed competence as the ultimate goal of the educational trajectory according to Bloom's taxonomy have been created. The use of web-resources in technical disciplines at a university for the acquisition of professional competences is presented in the form of a network graph, the optimization of which provides recommendations for building an educational trajectory. **Conclusions.** The e-learning management system of the technical profile disciplines at the university is an information technology that ensures the implementation of an individual approach to learning and the gradual assimilation of educational material according to the principle "from simple to complex". According to the functional purpose, learning tools can be divided into elements of the traditional system, which provide for an off-line learning format and elements of the distance learning system, which are part of the complex. In general, information technology for the acquisition of professional competences can be based on an educational trajectory based on Bloom's taxonomy. In order to create conditions for effective information interaction between teachers and students, integration of applied software products, databases, as well as other teaching aids and methodological materials that provide and support the educational process, it is advisable to conduct it through decentralized placement of teaching materials on relevant web resources and organization of intermediate control in a manner sufficient to conclude on the formation of professional competence.

Keywords: information technology; educational disciplines; higher education; electronic Learning Management system; Bloom's taxonomy; network graph; acquiring of professional competence.

Introduction

Formulation of the problem and research tasks. Today it is hard to imagine the educational process in higher education without the use of information technology. It is generally accepted that the use of information technologies can significantly improve the efficiency of the educational process, organize the interaction of all learning subjects in a new way, and build an educational system in which students would be active and equal participants. While understanding such a student-centered education strategy, it is impossible not to take into account the circumstances and current challenges.

The search for ways to solve this problem showed that the topic of development and application of new innovative approaches and learning technologies that can meet today's requirements has gained great popularity.

Back in 2020, due to the COVID-19 pandemic, distance learning was widespread in Ukraine. This experience came in handy due to a full-scale attack by Russia. Internal and external migration, shelling, lack of Internet or gadgets are modern challenges to education and, accordingly, to information technologies as well. In the conditions of a global pandemic, military actions on the territory of Ukraine, the implementation of systematic missile attacks by the aggressor on training centers and training grounds, the lack of a sufficient number of training samples for the training of highly qualified specialists from various complex technical systems, the question of high-quality training in a short period of time for a large number of learners with a minimum number of physical elements of learning. Providing training centers with a sufficient amount of equipment and machinery in a short period of time is an urgent problem in such conditions.

The search for ways to solve this problem has shown that the development and application of new innovative approaches and learning technologies that can meet today's requirements have gained great popularity.

But it is the modern circumstances that impose certain requirements on IT [1, 2]. So, they are: the formation of a web-space, such that traditional means (collection) can be replaced without losing the quality of practical skills; search on the Internet with the possibility of educational and methodological materials, their effective interaction according to algorithms that would ensure optimal use of resources and efficiency from the technical and methodological component; a flexible mechanism for developing educational trajectories taking into account the circumstances (online learning, asynchronization of the educational process, etc.); impacts and effective use of materials according to selected criteria.

Analysis of recent research and publications. The definition of IT is given in sources from the end of the last century. During this long journey, the definition was refined from all sides according to the field of application. We will provide a legal definition that can be used as a reference for this work. By information technology we will understand a purposeful, organized set of information processes using computing tools that provide high data processing speed, fast information search, data distribution, access to information sources regardless of their location [3]. Publications in this field are mainly declarative in nature, defining the main characteristics and properties.

The basic principles of IT construction defined in a number of sources [4, 5] will be useful. This is an interactive (dialog) mode of working with a computer; integration (docking, interconnection) with other software products; flexibility of the process of changing both data and task statements. But these are obvious slogans without implementation mechanisms.

When narrowing down to the field of education, in particular higher education, the approach to understanding the information technology of education is considered in various descriptive aspects. Most of the publications are dedicated to the mechanism of the formation of the web space. In this regard, some researchers define the information technology of education as scientific knowledge that investigates the peculiarities of the entire educational process. Others see technology as a way of understanding. But, according to experts, only simple linear storage of information is implemented as the most simple but extensive process, all the more devoid of interactivity. To be fair, the authors have both the theory and practice of filling the environment with educational and methodical materials, such as 3D-tours, tests and so on [6–8].

Developers of information technologies in education specify the individualization of educational behavior, believing that the characteristics of a person-oriented approach to learning are most clearly manifested in it: flexibility, modularity, accessibility, profitability, mobility, technology, social equality, internationality.

Thanks to modern platforms and software, there is an opportunity to develop innovative forms and techniques in educational activities. One of the ways to solve the mentioned problem is the use of modern tools and the development of e-learning electronic management system (ELMS) of relevant profile orientations. In the vast majority, ELMS only performs the functions of a virtual repository, where educational materials are stored − from electronic notes to work programs of educational disciplines.

The possibility of automatic processing of a large number of tests when using the control-diagnostic module of the complex is considered as a positive aspect of using ELMS. But the procedure for using such a module in the context of the effectiveness of the functioning of the entire ELMS has not been sufficiently studied. The criterion for optimizing the processing process is the timeliness of providing information to the user. Moreover, the developers of ELMS do not take into account the limitations on resources, in terms of time.

The development and use of a wide range of electronic educational resources is considered one of the promising areas of the education system, in particular higher education. Among the variety of electronic educational resources, the indisputable advantage belongs to ELMS are electronic learning means of the new generation and are focused on the innovative development of education. A specific feature of ELMS is the integration into a single system of electronic training tools of various natures [9–11].

One of the characteristics of the educational environment is the provision of access for students and teachers to structured educational and methodological materials, electronic learning management system and their use in any place, at any time and at any pace. In addition to the availability of educational material, they provide students with the opportunity to communicate with the teacher, receive online consultations, as well as the opportunity to receive individual "navigation" in mastering disciplines.

Specialists determine the importance of methodical and mathematical support of information technology and its primacy in relation to software, information, personnel, organizational and ergonomic support.

Information and organizational support are regulated by the university standards, educational programs, etc. [12, 13].

The software is developed in various variations [14–16]. However, software, like other material, is designed to implement the methodology. No detailed, and most importantly, scientifically based methodology for constructing the trajectory has been proposed. It is not defined according to which efficiency criteria it should be considered optimal.

Unsolved issues of what limitations should be taken into account during development and what is the purpose of creating this IT; which may be an opportunity to make changes when external influences change, to adjust software, information, personnel, organizational and ergonomic support.

Therefore, the construction of information technology that ensures the effective use of web-resources from educational disciplines of a technical profile in higher education for the acquisition of professional competences in modern conditions is a **relevant** task.

The **goal** of the study is the development of information technology ensures the effective use of web-resources in technical disciplines at a university for the acquisition of professional competencies in modern conditions. **The tasks** to be solved are:

− to organize the web environment in the e-learning management system (ELMS) for studying the discipline in a technical university on the principles of information technology;

− to construct an educational trajectory for the acquisition of professional competencies in technical disciplines at a university according to Bloom's taxonomy;

− to search ways to optimize the processing of information on web resources using the mathematical apparatus of graph theory.

Main material

1. IT acquisition of the necessary web-environment from the e-learning management system of educational technical discipline according to the information technology construction principles

The goal of IT is the development of data for human analysis and making appropriate decisions based on them, it is proposed to present IT development in the form of a "black box" [17].

Therefore, as the object of influence we'll consider the development of IT technology of the acquiring professional competencies in educational disciplines of a technical profile in a university. In this case, according to the principles of the "black box", students form the input parameter stream *X* traditionally called factors.

Y parameters define specialists with formed competencies, they form the output flow. In the literature, they are called optimization parameters, which successfully reflects the task of building an educational trajectory with certain criteria

W influences the process of competence formation and is determined by measures of technical, software, information, personnel and ergonomic support, namely: requirements of the standards and the educational program, evaluation criteria, requirements for training in dual education, in conditions of war. These influences can be classified as control ones.

Another group of influences consists of the so-called mechanisms of acquiring the necessary competences when studying the discipline, namely: material training tools (books, notes, posters), a classroom, the teacher's personality as personnel, organizational and ergonomic support, the electronic learning management system as methodological support includes an electronic book, electronic graphic material (poster, table, diagram, figure), presentation, educational video, summary form (interactive notes) [18]. The illustration of these provisions is presented in the Fig. 1.

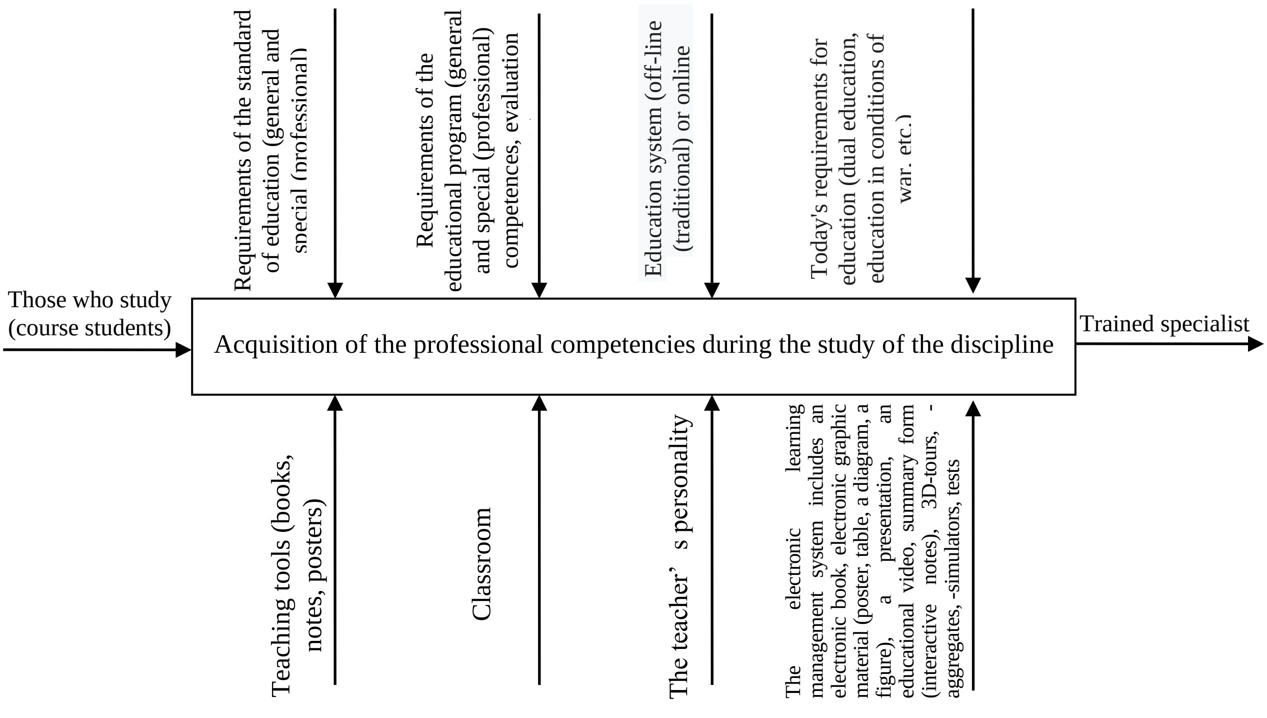

Fig. 1. The information technology of the acquiring professional competencies process during the study of the discipline as the "black box" and the place and role of ELMS in the process of training primary discipline

2. Electronic learning management system for the professional training in studying the discipline in a technical university

Let's consider an electronic Learning Management system (ELMS) as a didactic system that integrates applied software products, databases, and other didactic tools and methodological materials that provide and support the educational process in order to create conditions for pedagogical activity of information interaction between teachers and students. It is envisaged that the e-learning Management System will be used as an interactive tool for studying, for example, the structure and a vehicle operation ensuring the implementation of an individual learning approach and a vehicle gradual mastery on the principle of "from simple to complex" through the decentralized placement of didactic materials on the relevant web resources. The organization of the web resources will ensure that students acquire theoretical knowledge and practical skills, namely:

− the location of control, communication instrumentation and other elements inside the vehicle;

− the structure of components, assemblies and units, electrical equipment of the sample;

− the procedure for preparing the vehicle for operation in summer and winter conditions; actions to start the engine in different conditions in different permitted ways;

− monitoring the operation of engine systems with different engine modes;

− actions in cases of failure to operate the engine; and the operation of the engine in different modes.

Based on these considerations, the ELMS can be developed by the scientific and pedagogical staff of the department in the field of activity, covering several academic disciplines. The main blocks that form the overall structure of the ELSM include the following.

1. Software and information contains information about the author, department, discipline, specialties for which the complex is intended, the content of the complex, a list of abbreviations if necessary, the program of the discipline.

2. Educational and methodological blocks based on the content modules, the sequence of which coincides with the curriculum.

The content modules are filled with:

− theoretical (lecture) materials; educational and practical materials (exercises, tasks, problems);

− methodological materials (guidelines, instructions for laboratory work, individual, own-work and other types);

− questions (tests) for self-control;

− list of references and links to web-resources.

3. The control block contains materials for the final control of students' activities (questions for the exam and the final test task for the entire educational material).

4. The educational and research blocks contain topics of creative tasks, abstracts, educational and research tasks, qualification works, etc.

5. The auxiliary block filled with video, audio, multimedia materials and an electronic manual, the material of which can be processed on a convenient portable device (phone, smartphone, netbook, book reader, etc.).

In order to visualize the place and role of the e-learning Management

System in the process of studying a discipline, a corresponding flowchart has been developed [19] (Fig. 2).

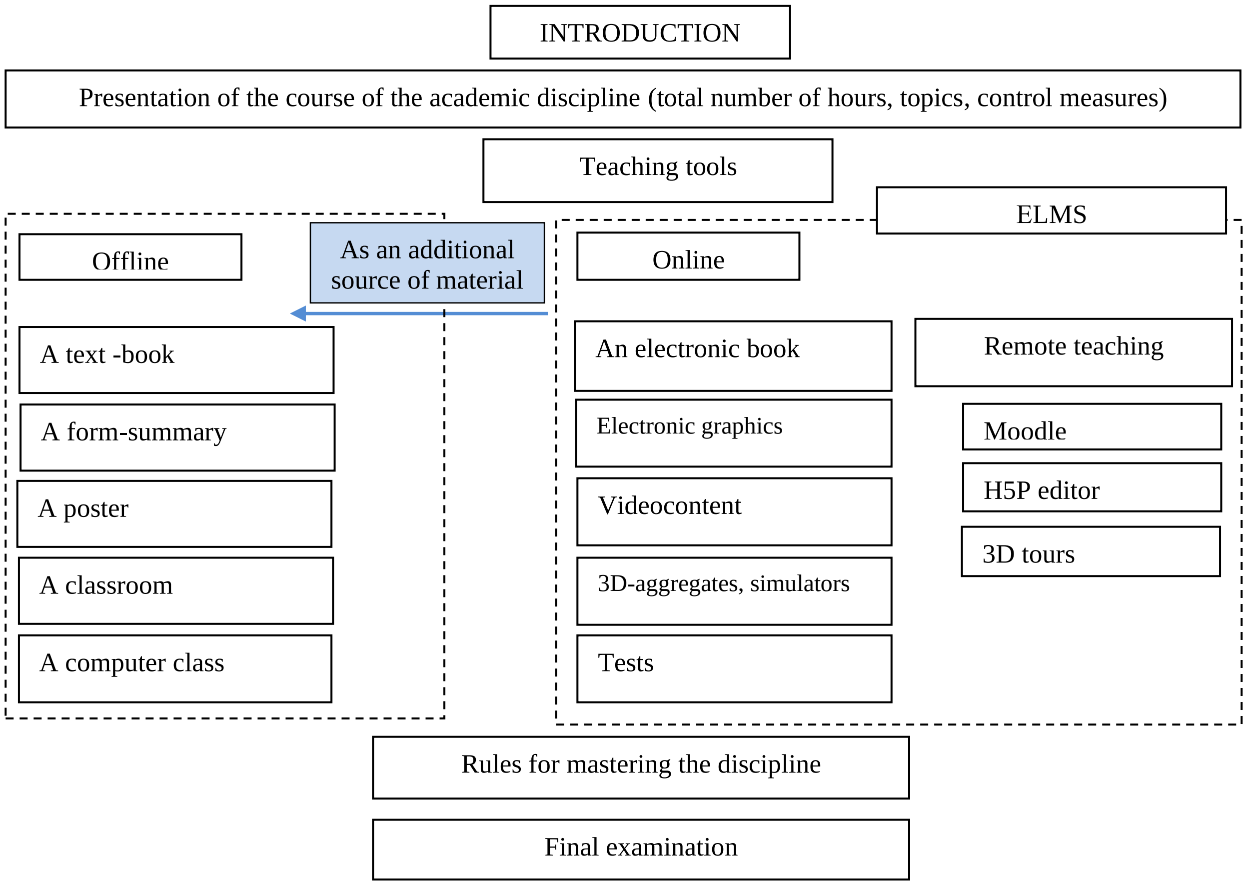

Fig. 2. The place and role of the e-learning Management System in the process of studying a discipline

The flowchart shows that the e-learning Management System can be considered as a tool for mastering a discipline within the framework of the general information technology of acquiring professional competencies.

According to the functional purpose, learning tools can be divided into elements of the traditional system, provide for an off-line learning format and elements of the distance learning system that are part of the ELMS.

At the same time, when studying material in a particular discipline, each block can be used several times.

In this case, the task of building a learning path that would be optimal in a certain sense in terms of the order of use of the e-learning Management System blocks arises.

Illustrative elements of the ELMS are shown in the Fig. 3 and Fig. 4. Namely, Fig. 3 is devoted the operation of the control block.

One can see a form of the multiple choice test questions for the control students.

Fig. 4 describes the operation of the educational block.

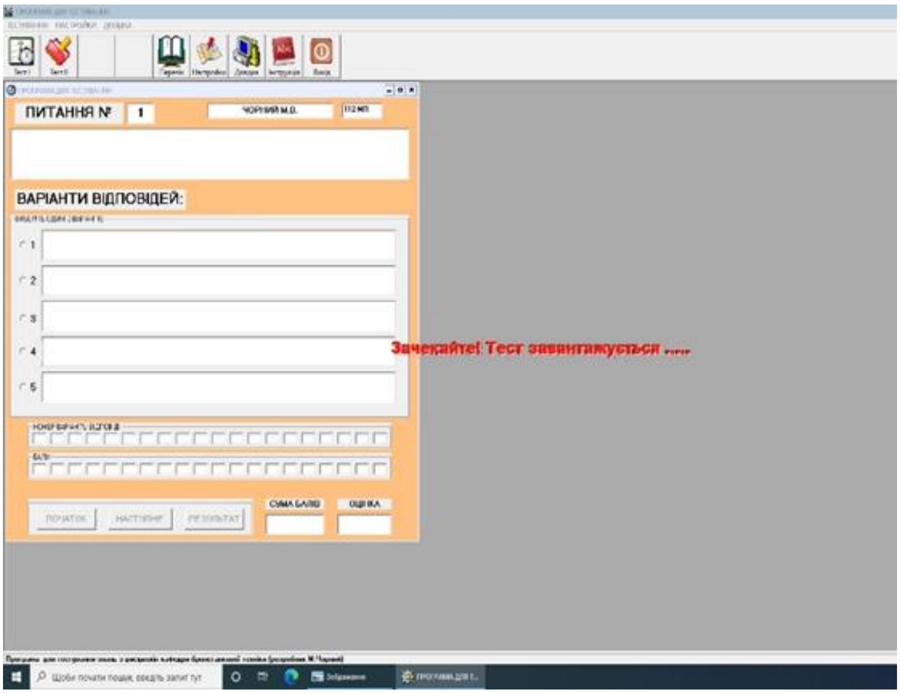

Fig. 3. A fragment of the operation of the control block

Fig. 4. A fragment of the operation of the educational block

3. Functional distribution of the e-learning Management System training tools in the field of information education technology

The technology of programmed learning involves the receipt of portions of information (text, graphic, video − it all depends on technical capabilities) in a certain sequence and provides control over learning at points in the course determined by the teacher.

Thus, increasing the effectiveness of learning the material, ensuring the active participation of students in the learning process requires the use of a significant number of tasks and exercises that are diverse in both content and purposes.

Tasks and exercises can be classified according to the following criteria:

− the degree of creativity means recognizing (checking the level of perception, awareness, memorization of material), transformative (applying the acquired knowledge according to a model or in a similar situation, developing skills) and constructive (tasks of a creative nature);

− purposes mean preparatory (activation of students' basic knowledge, preparation of students for the perception of new material), educational (formation of concepts and mastering ways to find them, consolidation and improvement of skills), generalizing (problem tasks of a mainly practical nature, creative tasks), control tasks (testing of acquired knowledge, skills and abilities);

− mandatory means tasks are mandatory and additional tasks for those wishing to deepen their knowledge;

− degree of independence: frontal, group and individual;

− the form of conduct means oral, written and experimental;

− degree of complexity means: ordinary and complicated;

− location means classroom and home.

Thanks to the use of computer technology (which most universities are equipped with today), we have the opportunity to provide each student with didactic material for classroom work presented in a system of tasks, in the process of which the student learns, generalizes, and consolidates the material.

So, the e-learning Management System as a methodical support of information technology of the acquiring professional competencies should ensure the setting of such training tasks and work with:

− an electronic book (including a textbook, a manual, a formalized summary form);

− electronic graphic material (a poster, a table, a diagram, a figure);

− videocontent;

− remote teaching and checking of the learning level (including Moodle, H5P editor, 3D tours);

− virtual training tools (including 3D- aggregates, 3D-simulators;

− means (devices) for checking knowledge and skills (including tests) [19].

At the same time, when studying material in a certain academic discipline, each block can be used several times. In this case, there is the task of building a learning trajectory that would be optimal in a certain sense from the point of view of the ELMS blocks engagement order [20, 21]. The authors propose the construction of an educational trajectory for the acquisition of professional competences in academic disciplines of a technical profile in higher education according to Bloom's taxonomy.

In general, the functional distribution of training tools in the e-learning Management System is presented in Fig. 5.

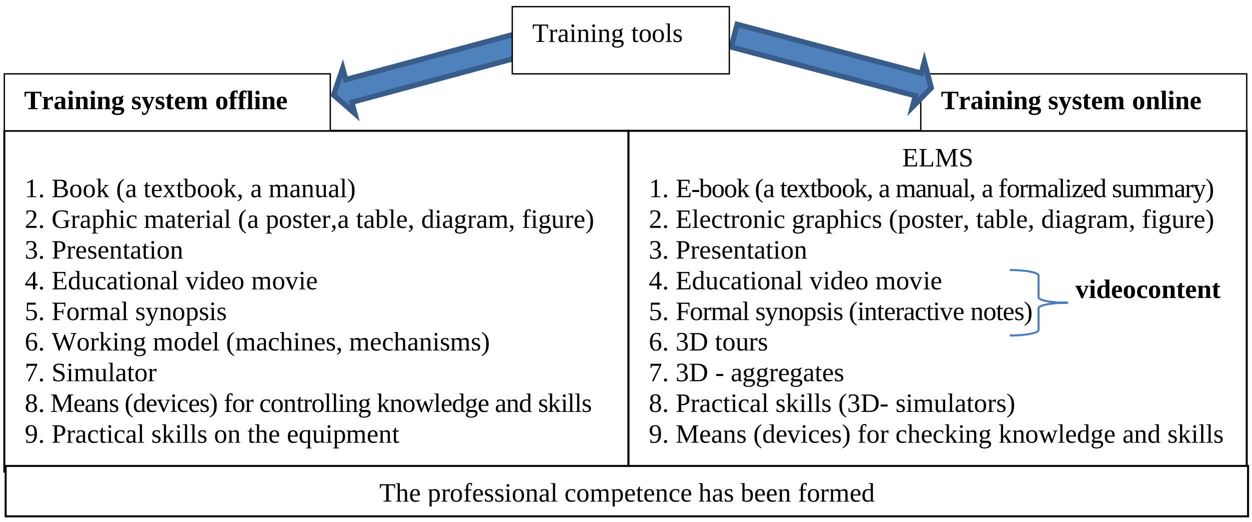

Fig. 5. Functional distribution of training tools in the e-learning Management System

4. Educational Trajectory in e-learning Management Systems Based on Bloom's Taxonomy

In general, the information technology of acquiring professional competencies can be based on an educational trajectory built according to Bloom's taxonomy.

Taking into account the Bloom's taxonomy [22] and functional distribution of training tools in the Learning tools in the e-learning Management System one can be distributed in such a way:

− the level "remember" includes such tools as an e-book (a textbook, a manual) (1), an electronic graphic material (a poster, a table, a diagram, a figure) (2), a presentation (3), an educational video movie (4) and a formal synopsis (interactive notes) (5);

− the level "understand" includes 3D tours (6) as the ELSM tools;

− the level "apply" includes 3D - aggregates (7);

− analogously, event (8), defines the mastery of practical skills using 3D simulators, involves the skills of level "analyze" and "evaluate" one's performance;

− the structure of the e-learning Management System provides means (devices) for controlling knowledge and skills that contribute to the formation of synthesis skills (based on the results of negative feedback from other events. This connection is realized through the level “create” (9).

At the same time, it is possible to re-work the elements of the e-learning Management System if it is necessary to improve the quality of learning. Such a situation will arise, in particular, during the intermediate control of knowledge and will be schematically implemented in the form of negative relationships in the algorithm.

In general, these considerations are illustrated in Fig. 6.

Thus, the process of acquiring competence in an academic discipline can be described by a list of events and activities as a set of measures that reflect its essence and the relationship between individual procedures (activities).

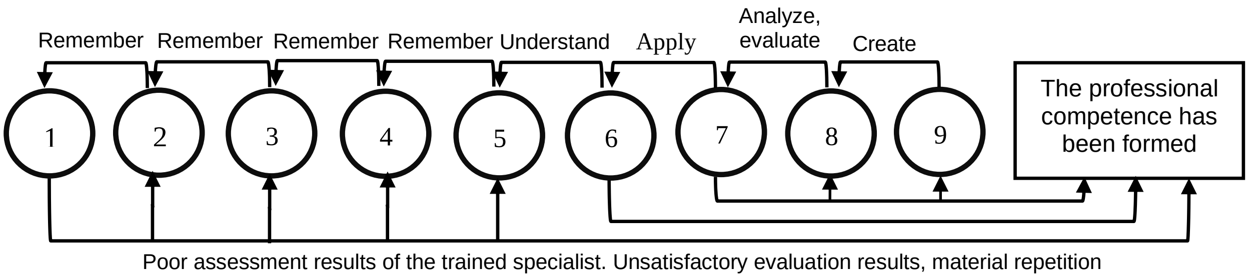

Fig. 6. Educational Trajectory in e-learning Management Systems Based on Bloom’s Taxonomy

5. Optimization the processing of information on web resources for the acquisition of professional competencies in technical disciplines at a university using the mathematical apparatus of graph theory

5.1. A graphic network model for construction an educational trajectory in accordance with the ELMS structure. Authors consider network planning is considered a general tool of project management allows for the most efficient use of available resources, both material and non-material [23, 24].

To construct a network schedule for the acquisition of competence in an educational discipline, we will define the following events. Gaining knowledge from:

1 – an electronic book (a textbook, a manual);

2 − an electronic graphic material (a poster, a tables,a diagrams, a figure);

3, 4 − video content (a presentation, an educational video movie);

5 − obtaining knowledge from the summary form (interactive notes);

6 − formation of understanding by mastering the 3D tour;

7 – application of skills on 3D aggregates;

8 − mastery of practical skills;

In addition, the control of knowledge and skills with the use of appropriate means (devices) as point 9 in the tducational trajectory.

Thus, the process of acquiring competence in an academic discipline can be described by a list of events and activities as a set of measures that reflect its essence and the relationship between individual procedures (activities).

Events 1-5 will be attributed to the lower levels of Bloom’s taxonomy, namely, they correspond to the “knowledge” category.

Events 6 and 7 fall under the category of “understanding” and “application” respectively.

For analogical reasons, event 8, which determines the mastery of practical skills with the help of 3D aggregates and simulators involves the skills of analyzing and evaluating one's activities.

It should be noted that the structure of ELMS provides means (devices) for controlling knowledge and skills, which contribute to the formation of synthesis skills based on the results of negative feedback from other events.

This relationship is implemented through event 9 and failure intensity.

Thus, the process of acquiring competence in an educational discipline can be described by a list of events and works, as a set of measures that reflect its essence and the relationships between individual procedures (measures).

So, the procedures for applying training tools for the competencies formation in terms of the network schedule are presented in Table 1.

Finally, the network graph will look as shown in Fig. 7.

5.2. Optimization of the process of formation of professional competence along the critical path. Authors use the classical theory of network planning and management to optimize the graph in order to reduce the time of work and rational use of forces and resources. For this, each work must be put in accordance with some numerical estimate that characterizes its duration.

The duration of the work was determined experimentally in the course of conducting a pedagogical experiment at the Armored Vehicles Department of Hetman Petro Sahaidachnyi National Army Academy in accordance with the training programs according to the profile of the department.

Taking into account the specifics of the subject area, it is suggested to use the percentage of work in the total time budget for the formation of professional competence as numerical estimates (Table 2) [19].

Table 1 − **The competencies formation in terms of the network schedule**

№	Event number	Numbers of works	Title and content of works
1	0	0	The beginning
2	1	0-1	Obtaining knowledge from an electronic book a (textbook, a manual)
3	2	0-2 1-2	Acquiring knowledge from electronic graphic material (a poster, a table, a diagram, a figure)
4	3	0-3 1-3 2-3	Acquiring knowledge from video content (a presentations)
5	4	0-4 1-4 2-4 3-4	Acquiring knowledge from video content (an educational movie)
6	5	0-5 1-5 2-5 3-5 4-5	Obtaining knowledge from the summary form (interactive notes)
7	6	5-6	Formation of understanding by mastering the 3D-tour
8	7	6-7	Application of skills on 3D-aggregates;
9	8	7-8	Mastery practical skills on 3D aggregates and simulators;
10	9	6-9 7-9 8-9	Means (devices) of control of knowledge and skills
11	10	9-10	The professional competence has been formed (The end)

Table 2 − **Work duration in the network graph for construction an educational trajectory in accordance with the ELMS structure**

№	Work title	Duration, min.	Duration, % of the total working time of the material
1	0-1	15	2,42
2	0-2	35	5,65
3	0-3	40	6,5
4	0-4	10	1,62
5	0-5	10	1,62
6	1-2	35	5,65
7	1-3	40	6,5
8	1-4	10	1,62
9	1-5	10	1,62
10	2-3	40	6,5
11	2-4	10	1,62
12	2-5	10	1,62
13	3-4	10	1,62
14	3-5	10	1,62
15	4-5	10	1,62
16	5-6	5	0,81
17	6-7	5	0,81
18	7-8	90	14,52
19	6-9	45	7,26
20	7-9	45	7,26
21	8-9	45	7,26
22	9-10	90	14,52

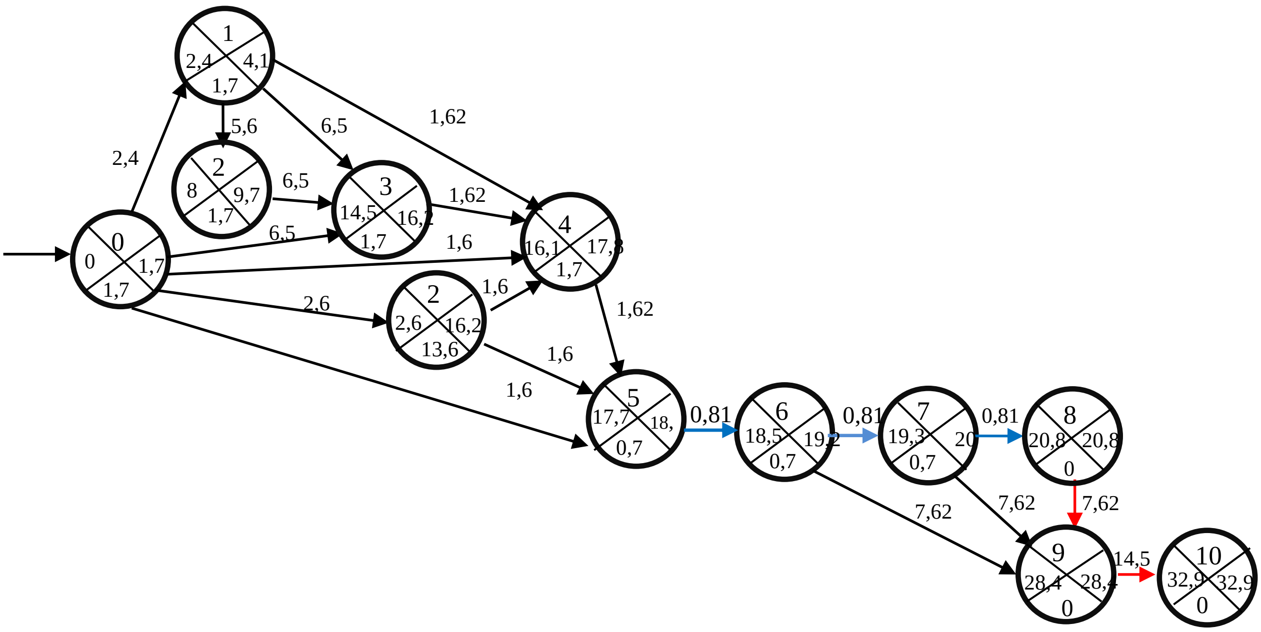

Fig. 7. Network graph of the formation of educational competence process in the ELMS

In accordance with the main provisions of network planning, it is proposed to optimize the schedule by redistributing the resources of works that are not on the critical path to work on the critical path, using additional resources and reducing the duration of some critical works by involving other specialists [25, 26].

As we can see, with the existing trajectory of the formation of professional competence, the works related to the control of knowledge and skills, which events are numbered 8, 9, are on the critical path.

In general, this does not involve a fundamental revision of the schedule, except for the improvement of the control process itself, but the defined approach allows optimizing the process of formation of educational competence as a whole.

Similarly, events numbered 5, 6, and 7 are the most "dangerous" for “hitting” the critical path.

In the terminology of the educational process, these proposals can be formulated as follows: it is advisable to increase the time for knowledge control and the ability and/or “parallelize the process” of checking each stage of educational competencies formation.

At the same time, it should be noted that the reduction of the critical path will be facilitated by the allocation of additional time due to 3D tours and 3D aggregates at each stage of competence formation.

In order to improve the functioning of ELMS, it is proposed to: clarify the time for acquiring knowledge from video content (presentations); from video content (educational movies).

5.3. The dynamic model for construction an educational trajectory in accordance with the ELMS structure.

We will correspond to each event the state of ELMS depending on the number of students who are in it. Based on these data, a dynamic its model can be built (Fig. 8).

This graph shows:

μ_0 – the intensity of students’ admission to ELMS;

μ_1 – the intensity of obtaining knowledge from an electronic book a (textbook, a manual);

μ_2 – the intensity of acquiring knowledge from electronic graphic material (a poster, a table, a diagram, a figure);

μ_3 –the intensity of acquiring knowledge from video content (a presentations);

μ_4 – the intensity of acquiring knowledge from video content (an educational movie);

μ_5 – the intensity of acquiring knowledge from the summary form (interactive notes);

μ_6 – the intensity of formation the understanding by mastering the 3D-tour;

μ_7 – the intensity of application the skills on 3D-aggregates and simulators;

μ_8 – the intensity of mastery practical skills on 3D aggregates and simulators;

μ_9 – the intensity of control of knowledge and skills;

μ_{10} – the intensity of students’ “graduation”.

Of course, at each learning evaluation stage of outcomes, materials are repeated in case of unsatisfactory results.

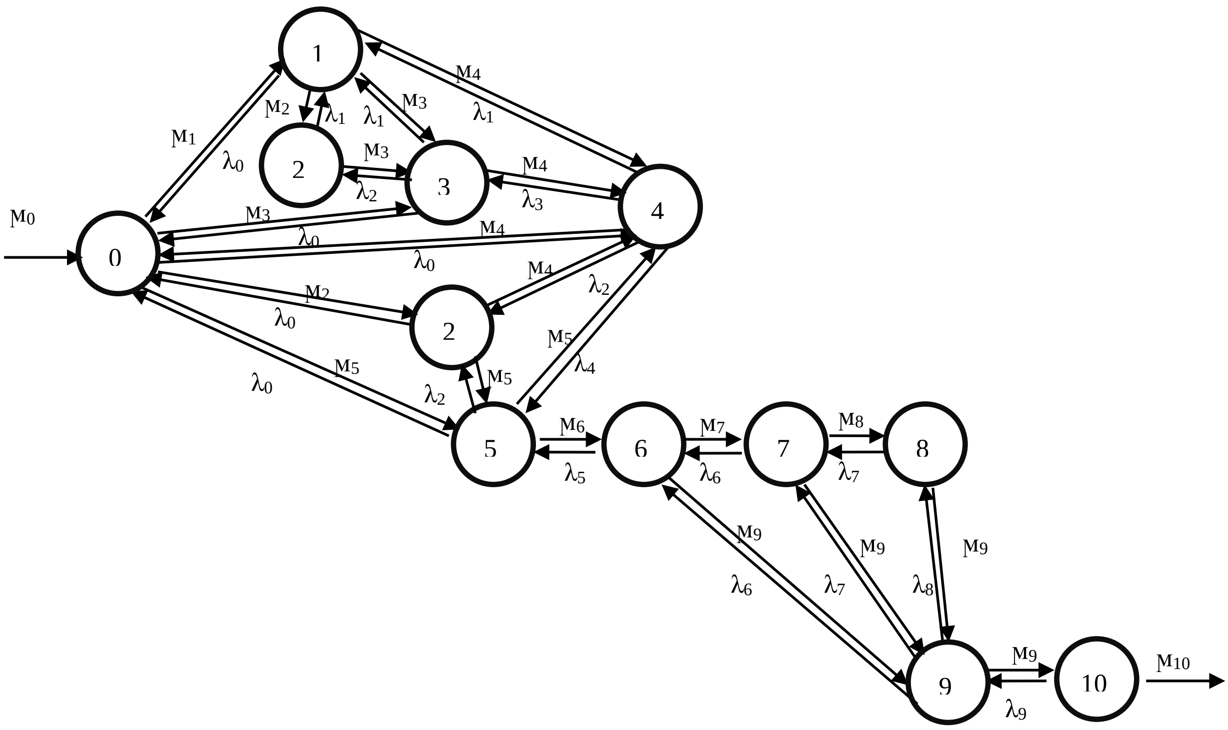

Fig. 8. Network state graph of the dynamic model of formation of professional competence in ELMS

Based on these considerations, λ is marked on the graph – the failure intensity of the corresponding state.

λ_1 – the intensity of rejections when learning from an e-book;

λ_2 – the intensity of failures when gaining knowledge from electronic graphic material

λ_3 – the intensity of refusals when gaining knowledge from the presentation;

λ_4 – the intensity of rejections when learning from educational movies;

λ_5 – intensity of failures when learning from interactive notes;

λ_6 – the intensity of failures when formation the understanding by mastering the 3D-tour;

λ_7 — the intensity of failures when applying skills on 3D aggregates;

λ_8 – the intensity of failures when practicing skills on 3D and augmented reality simulators;

λ_9 – the intensity of unsatisfactory results in the control of knowledge and skills.

These parameters of the model can be determined by statistical data [27].

According to the state graph (Fig. 8), for the average number of students in each *i*-th state n_i, $i=\overline{1,n}$, can be determined by the differential equations system (1)–(11):

$$\frac{dn_0(t)}{dt}=\mu_0 n_0(t)-\mu_1 n_1(t)-\mu_3 n_3(t)-\\-\mu_4 n_4(t)-\mu_5 n_5(t)+\lambda_0 n_1(t)+\lambda_0 n_2(t)+\\+\lambda_0 n_3(t)+\lambda_0 n_4(t)+\lambda_0 n_5(t); \quad (1)$$

$$\frac{dn_1(t)}{dt}=\mu_1 n_0(t)-\mu_2 n_1(t)-\mu_3 n_1(t)-\mu_4 n_1(t)-\\-\lambda_0 n_1(t)+\lambda_1 n_2(t)+\lambda_1 n_3(t)+\lambda_3 n_4(t); \quad (2)$$

$$\frac{dn_2(t)}{dt}=\mu_2 n_0(t)-\mu_2 n_2(t)+n_1(t)-\mu_5-\\-\lambda_0 n_2(t)-\lambda_1 n_2(t)+\lambda_2 n_4(t)+\lambda_2 n_3(t)+\lambda_2 n_5(t); \quad (3)$$

$$\frac{dn_3(t)}{dt}=\mu_3 n_9(t)+\mu_3 n_1(t)+\mu_3 n_2(t)-\mu_4 n_3(t)-\\-\lambda_0 n_3(t)-\lambda_1 n_3(t)-\lambda_2 n_3(t)+\lambda_3 n_4(t); \quad (4)$$

$$\frac{dn_4(t)}{dt}=\mu_4 n_1(t)+\mu_4 n_3(t)+\mu_4 n_0(t)-\mu_5 n_4(t)-\\-\lambda_3 n_4(t)-\lambda_1 n_4(t)-\lambda_6 n_4(t)-\lambda_2 n_4(t)-\lambda_4 n_5(t); \quad (5)$$

$$\frac{dn_5(t)}{dt}=\mu_5 n_0(t)+\mu_5 n_0(t)-\mu_6 n_0(t)+\mu_5 n_2(t)-\\-\lambda_4 n_5(t)+\lambda_5 n_6(t)-\lambda_0 n_5(t)-\lambda_2 n_5(t); \quad (6)$$

$$\frac{dn_6(t)}{dt}=\mu_6 n_5(t)-\mu_7 n_6(t)-\mu_9 n_6(t)-\\-\lambda_5 n_6(t)+\lambda_6 n_7(t)-\lambda_6 n_9(t); \quad (7)$$

$$\frac{dn_7(t)}{dt}=\mu_7 n_6(t)-\mu_8 n_7(t)-\mu_5 n_7(t)+\lambda_7 n_9(t); \quad (8)$$

$$\frac{dn_8(t)}{dt}=\mu_8 n_7(t)-\mu_9 n_8(t)-\lambda_7 n_8(t)+\lambda_8 n_9(t); \quad (9)$$

$$\frac{dn_9(t)}{dt}=\mu_9 n_8(t)+\mu_9 n_7(t)+\mu_9 n_6(t)-\\-\lambda_7 n_9(t)-\lambda_6 n_9(t)-\lambda_6 n_9(t)+\lambda_6 n_{10}(t); \quad (10);$$

$$\frac{dn_{10}(t)}{dt}=\mu_9 n_9(t)-\lambda_9 n_{10}(t)-\mu_{10} n_{10}(t) \quad (11)$$

with initial conditions (12 –13):

$$n_0(0)=N_0;\ n_1(0)=N_1;\ n_2(0)=N_2;\\ n_3(0)=N_3;\ n_4(0)=N_4;\ n_5(0)=N_5;\\ n_6(0)=N_6;\ n_7(0)=N_7;\ n_8(0)=N_8;\\ n_9(0)=N_9;\ n_{10}(0)=N_{10}; \quad (12)$$

$$n_0(t)+n_1(t)+n_2(t)+n_3(t)+\\+n_4(t)+n_5(t)+n_6(t)+n_7(t)+\\+n_8(t)+n_9(t)+n_{10}(t)=N(t), \quad (13)$$

where $i=\overline{1,n}$ – the number of system states according to the educational trajectory for the acquisition of professional competencies; $t\in[0,T]$,

T – a certain period of time for the acquisition of professional competence;

N_i − the number of students in the *i*-th state at the initial moment of time *t*=0.

The solution of the system of differential equations (1) − (13) will be the dependencies of the average number of students in each state in time.

$$N(t)=n_0(t)+n_1(t)+n_2(t)+n_3(t)+\\+n_4(t)+n_5(t)+n_6(t)+n_7(t)+n_8(t)+\\+n_9(t)+n_{10}(t)=\sum_{i=0}^{10} n_i(t), \quad (14)$$

where $N(t)$, $i=\overline{1,n}$ – the number of students, in the *i*-th state of ELMS according to the learning tool at the moment; T – a certain period of time.

On the basis of this solution, a dynamic analysis of the work of ELMS for a certain period of time T can be done.

Correlations between different ones $N_i(t)$ will make it possible to evaluate the efficiency indicators of ELMS. Thus, the load factor of the *i*-th training tool

$$K_з=\frac{N_i(t)}{N(t)} \quad (15)$$

where $N(t)$ – the total current number of students at ELMS.

Thus, for the study of the process of formation of professional competence in ELMS, it is advisable to use the model as such, which takes into account changes over time and states according to statistical data.

5.4. The results of a dynamic analysis of the acquiring professional competencies in the environment of an e-learning methodological complex by ELSM. According to [27, 28] the student's transition from one state to another within the ELMS is carried out with intensities, μ_i or λ_i, depend on the influence of the external environment and controlling influences from the control system.

The number of students in each *i*-th state n_i, $i=\overline{1,n}$, can be determined by the system of differential equations (1) – (13).

According to the pedagogical experiment, two groups were selected: control and test ones.

Classes in the control group were conducted in a traditional way, and in the test group – with the help of the ELMS.

And on the basis of the statistical data processing, the corresponding values of the state to state transitions intensities were determined (Table 3).

Table 3 – **The values of the state to state transitions intensities**

№	Name	Value, man/hour
1	μ_0	0,633
2	μ_1	3,8
3	μ_2	1,63
4	μ_3	1,43
5	μ_4	5,7
6	μ_5	5,7
7	μ_6	1,14
8	μ_7	1,14
9	μ_8	0,633
10	μ_9	0,633
11	μ_{10}	0,633
12	λ_0	3,8
13	λ_1	5,7
14	λ_2	1,425
15	λ_3	5,7
16	λ_4	5,7
17	λ_5	1,14
18	λ_6	1,14
19	λ_7	1,27
20	λ_8	1,27
21	λ_9	0,63

So, according to the table 3 data the system (1) – (13) will look like

$$\frac{dn_0(t)}{dt} = 0,63 \cdot n_0(t) - 3,8 \cdot n_1(t) - 1,43 \cdot n_3(t) - -5,7 \cdot n_4(t) - 5,7 \cdot n_5(t) + 3,8 \cdot n_1(t) + 3,8 \cdot n_2(t) + +3,8 \cdot n_3(t) + 3,8 \cdot n_4(t) + 3,8 \cdot n_5(t); \quad (16)$$

$$\frac{dn_1(t)}{dt} = 3,8 \cdot n_0(t) - 1,63 \cdot n_1(t) - 1,63 \cdot n_1(t) - -1,43 n_1(t) - 3,8 \cdot n_1(t) + 5,7 \cdot n_2(t) + +5,7 \cdot n_3(t) + 5,7 \cdot n_4(t); \quad (17)$$

$$\frac{dn_2(t)}{dt} = 1,63 \cdot n_0(t) + 1,63 \cdot n_1(t) - 3,8 \cdot n_2(t) - -5,7 \cdot n_2(t) + 1,425 \cdot n_4(t) + 1,425 \cdot n_3(t); \quad (18)$$

$$\frac{dn_3(t)}{dt} = 1,43 \cdot n_0(t) + 1,43 \cdot n_1(t) + 1,43 \cdot n_2(t) - -16,625 \cdot n_3(t) + 5,7 \cdot n_4(t); \quad (19)$$

$$\frac{dn_4(t)}{dt} = 5,7 \cdot n_1(t) + 5,7 \cdot n_3(t) + 5,7 \cdot n_0(t) - -3 \cdot 5,7 \cdot n_4(t) - n_4(t) \cdot \left(1,14 + 1,425\right) - 5,7 \cdot n_5(t); \quad (20)$$

$$\frac{dn_5(t)}{dt} = 5,7 \cdot n_0(t) + 5,7 \cdot n_0(t) - 1,14 \cdot n_0(t) - -5,7 \cdot n_5(t) + 1,14 \cdot n_6(t) - 3,8 \cdot n_5(t); \quad (21)$$

$$\frac{dn_6(t)}{dt} = 1,14 \cdot n_5(t) - 1,14 \cdot n_6(t) - 0,63 \cdot n_6(t) - -1,14 \cdot n_6(t) + 1,14 \cdot n_7(t) - 1,14 \cdot n_9(t); \quad (22)$$

$$\frac{dn_7(t)}{dt} = 1,14 \cdot n_6(t) - 6,96 \cdot n_7(t) + 1,27 \cdot n_9(t); \quad (23)$$

$$\frac{dn_8(t)}{dt} = 0,63 \cdot n_7(t) - 1,9 \cdot n_8(t) + 1,27 \cdot n_9(t); \quad (24)$$

$$\frac{dn_9(t)}{dt} = 0,63 \cdot n_8(t) + 0,63 \cdot \left(n_7(t) + n_6(t)\right) - -1,27 \cdot n_9(t) - 1,14 \cdot n_9(t) - 1,14 \cdot n_9(t) + 1,14 \cdot n_{10}(t); \quad (25)$$

$$\frac{dn_{10}(t)}{dt} = 0,63 \cdot n_9(t) - 0,63 \cdot n_{10}(t) - 0,63 \cdot n_{10}(t); \quad (26)$$

$$n_0(0) = 57; \quad n_i(0) = 0,\ i = \overline{1,10}. \quad (27)$$

It is assumed that there are no student deductions, i.e. the total number of students at the ELSM is constant.

Solving the system of equations (16) − (21) gives the time dependence of the students number in each state.

A dynamic analysis of the ELMS functioning and modeling of its state components should determine the optimal volume of the lecturer's workload and time reserve (Fig. 9). In this figure one can see the graphical dependence on time of the number of students in each state *n(0) − n(10)*.

As can be seen from the graph, the total number of 620 minutes, which corresponds to a little more than 10 hours of study time, is quite enough for the formation of professional competence within one topic of study of an academic discipline, which is evidenced by the attenuation of fluctuations.

Meanwhile, the graph of the dependence of the number of students, whose knowledge is subject to verification, indicates the inefficient work of point 5 and the ineffectiveness of point 9.

This confirms the recommendations for parallelization of the process and with intensity regulation and modeling of different options.

As an option to get rid of the "bottleneck" in the control of the acquisition of professional competences, it is proposed to organize an intermediate control after paragraphs 5-8 (Fig. 5), and a final control based on the results of the intermediate control.

To optimize the network schedule, it is suggested to change the works duration on the critical path by adding additional works for this purpose (Table 4).

In the terminology of the educational trajectory formation, such changes can be interpreted in the organization of intermediate control in such a way as to reduce the load on the final one.

This can happen when a student is expelled from studies or when such intermediate results are obtained that allow drawing a conclusion about the formation of professional competence without final control.

A fragment of the optimized network graph is shown in Fig. 10.

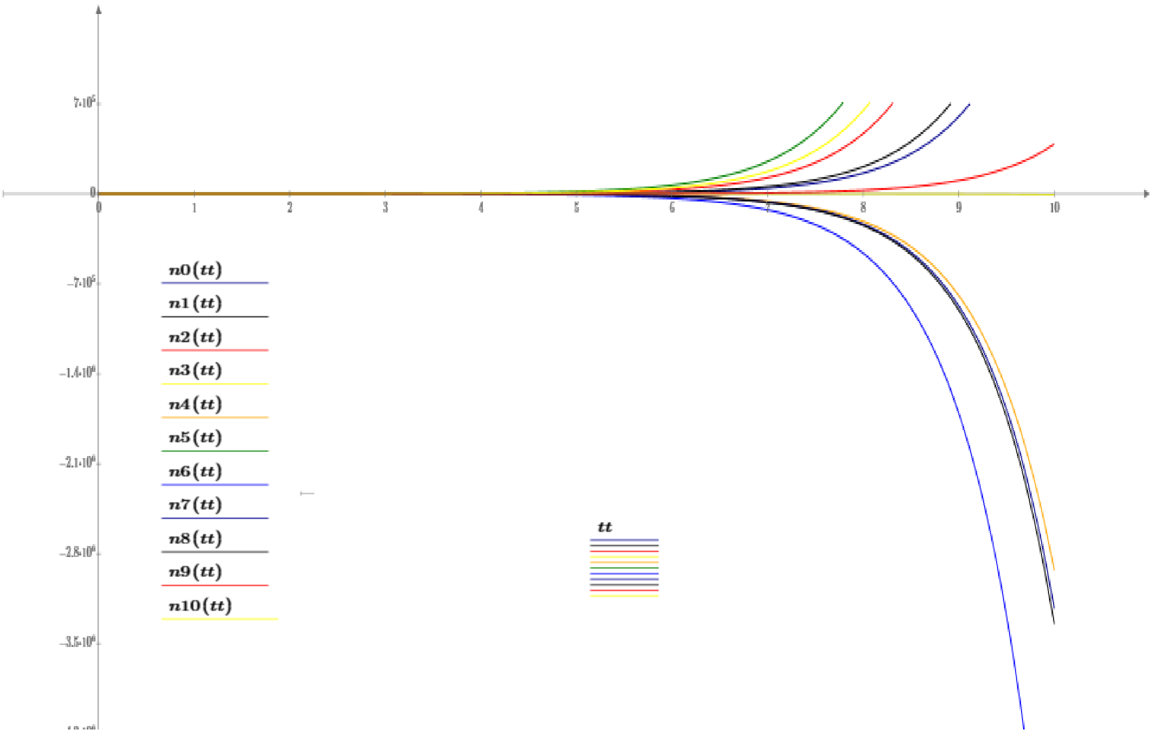

Fig. 9. The number of students in ELMS elements state

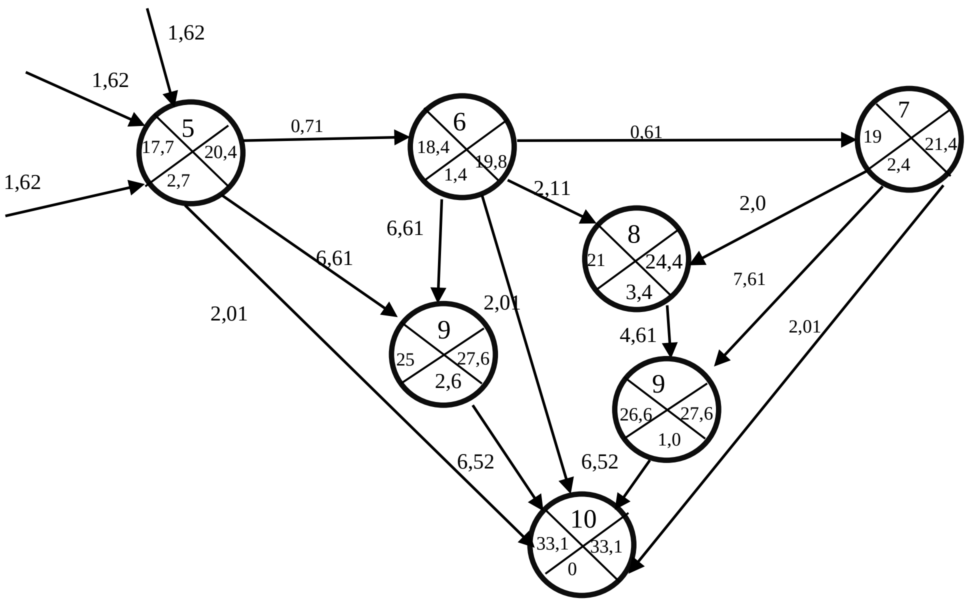

Fig. 10. The graphical dependence on time of the number of students in each state

Table 4 – **Modification of the of the network graph works for optimization**

Work title	Duration, % of the total working time of the material	Work title	Duration, % of the total working time of the material
5-6	0,71	7-8	2,00
5-9	6,61	7-9	7,61
5-10	2,01	7-10	2,01
6-7	0,61	8-9	4,61
6-8	2,21	8-10	2,01
6-9	6,61	9-10	6,52
6-10	2,01		

Based on the analysis of the graph, it can be concluded that such an organization of the process of acquiring professional competence does not have works on the critical path. At the same time, the total hour of training increases by 0.2% realistic from the point of view of organizing training.

According to the proposed method, the calculated values of states $n(0) - n(10)$ is shown in Fig. 11.

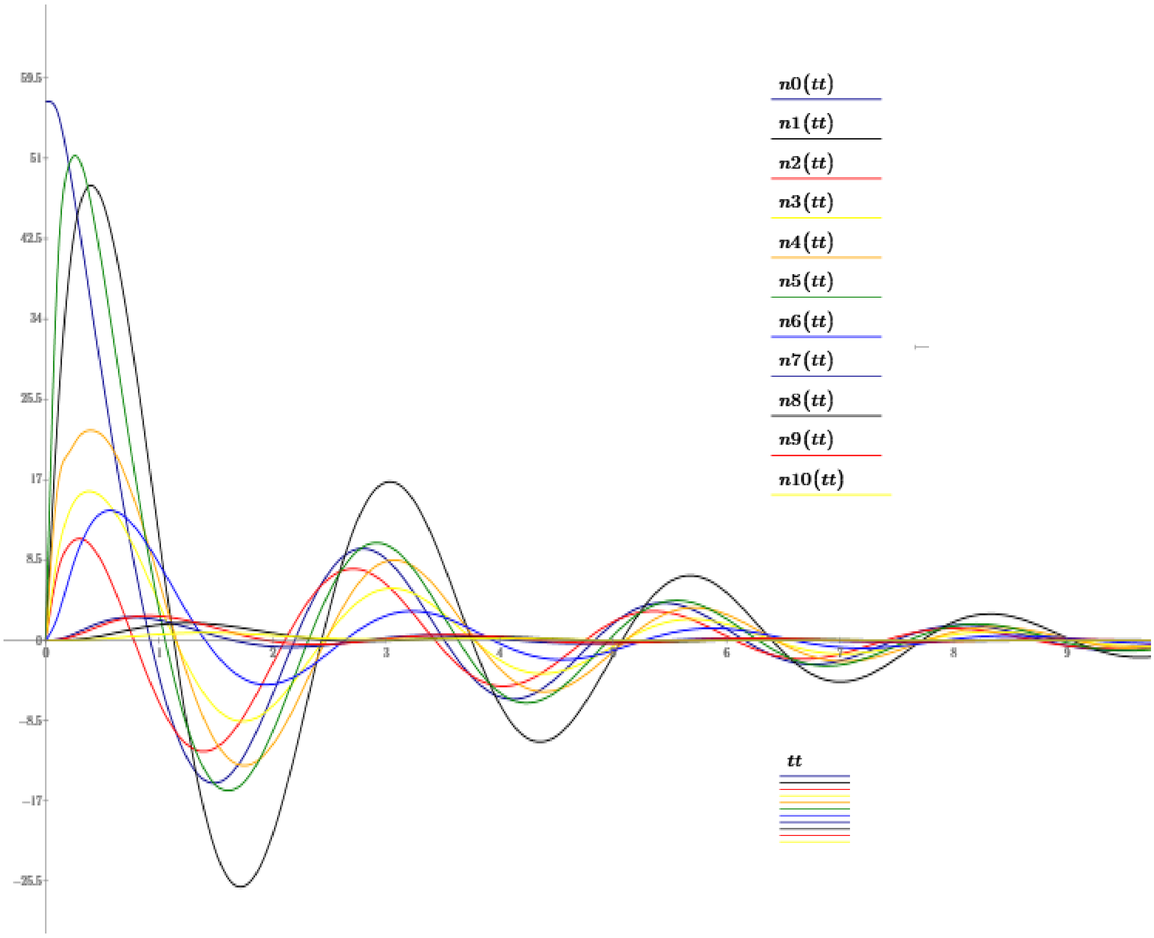

Fig. 11. Optimized loading of ELMS elements states relative to the number of students

In this version of the educational organization, all elements of the ELMS "work out" to achieve the result, and the number of students in each state gradually decreases without creating traffic jams.

Conclusions

1. The e-learning management system of the technical profile disciplines at the university is an information technology that ensures the implementation of an individual approach to learning and the gradual assimilation of educational material according to the principle "from simple to complex".

2. According to the functional purpose, learning tools can be divided into elements of the traditional system, which provide for an off-line learning format and elements of the distance learning system, which are part of the complex.

3. In general, information technology for the acquisition of professional competences can be based on an educational trajectory based on Bloom's taxonomy.

4. In order to create conditions for effective information interaction between teachers and students, integration of applied software products, databases, as well as other teaching aids and methodological materials that provide and support the educational process, it is advisable to conduct it through decentralized placement of teaching materials on relevant web resources and organization of intermediate control in a manner sufficient to conclude on the formation of professional competence.

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Інформаційна технологія процесу набуття фахових компетентностей у середовищі електронно-навчального методичного комплексу шляхом побудови освітньої траєкторії

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Анотація. Предметом вивчення в статті є побудова освітньої траєкторії у середовищі електронно-навчального методичного комплексу. **Метою статті** є розробка інформаційної технології, яка забезпечує ефективне використання web-ресурсів з навчальних дисциплін технічного профілю у виші для набуття фахових компетентностей в сучасних умовах. **Завдання дослідження**: Організація середовища електронно-навчального методичного комплексу за принципами побудови інформаційної технології; побудова за таксономією Блума освітньої траєкторії набуття фахових компетентностей з навчальних дисциплін технічного профілю у виші; пошук шляхів оптимізації обробки інформації web-ресурсів з використанням математичного апарату теорії графів; розробка рекомендації щодо побудови освітньої траєкторії набуття фахових компетентностей. **Отримані такі результати:** Процес набуття фахових компетентностей у web-середовищі електронно-навчального методичного комплексу поданий у структурі інформаційної технології. На основі проведеного функціонального розподілу засобів навчання створено блок-схему електронно-навчального методичного комплексу та алгоритм досягнення сформованої компетентності як кінцевої мети освітньої траєкторії за таксономією Блума. Використання web-ресурсів з навчальних дисциплін технічного профілю у виші для набуття фахових компетентностей подано у вигляді мережевого графа, оптимізація якого надає рекомендації щодо побудови освітньої траєкторії. **Висновки.** Електронно-навчальний методичний комплекс навчальних дисциплін технічного профілю у виші є інформаційною технологію, що забезпечує реалізацію індивідуального підходу до навчання та поетапне засвоєння навчального матеріалу за принципом “від простого до складного”. За функціональним призначенням інструменти навчання можна поділити на елементи традиційної системи, які передбачають off-line формат навчання та елементи системи дистанційного навчання, що є у складі комплексу. У загальному вигляді інформаційна технологія набуття фахових компетентностей може мати в основі освітню траєкторію, побудованою за таксономією Блума. З метою створення умов для ефективної інформаційної взаємодії між викладачами і студентами, інтеграції прикладних програмних продуктів, баз даних, а також інших дидактичних засобів і методичних матеріалів, що забезпечують і підтримують освітній процес, його доцільно проводити шляхом децентралізованого розташування дидактичних матеріалів на відповідних web ресурсах та організації проміжного контролю у спосіб, достатній для висновку про сформованість професійної компетентності.

Ключові слова: інформаційна технологія; навчальні дисципліни; електронний навчально-методичний комплекс; освітня траєкторія; таксономія Блума; мережний граф; сформованість професійної компетентності.