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COMPREHENSIVE ANALYSIS OF THE FUNCTIONING OF A UNIVERSITY DEPARTMENT AS A COMPLEX SYSTEM IN MODERN CONDITIONS

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Abstract. *This article presents the results of a comprehensive analysis of a university department as a complex system in order to identify weaknesses in the process of administering university departments in conditions of information singularity and crisis phenomena in society.*
Keywords: *university department, structural analysis, space-time analysis, functional analysis, complex system, formalization.*

Introduction

The task of creating an effective education and training management system has been relevant for more than 20 years. Every year, the contradictions between the enormous opportunities for digitalization of teaching and educational processes and outdated methods of teaching students in higher education are intensifying.

The system-cybernetic approach to the implementation of management in the field of education is based on the synthesis of a hierarchical set of models of various types.

In the light of modern innovations in the field of higher education, the task of creating a model of a support system for educational processes is one of the urgent tasks of digitalization of education and is considered not just as a task of developing the practice of strategic management in universities, but also as a decision support system for regulating the experience and expectations of students.

Digital transformation of learning processes creates the basis for competitive advantages and improving the quality of higher education [1, 2].

At the same time, to ensure the quality of education and organization of the educational process, it is necessary to consider the systemic functioning of the department as a basic unit of the university [3, 4].

To achieve this goal, it is necessary to determine which class of systems the university department belongs to. Unfortunately, in most educational and scientific literature the concept of "department" is interpreted as an educational system. This definition is correct, but it does not give a complete picture of the functionality and features of this, from our point of view, complex system.

The question arises: why study in detail and carefully the functionality of the department as the basic unit of a higher educational institution. In our opinion, the modern development of society is at a methodological turning point. In the theory of scientific revolutions [5], such a turning point is characteristic of the transition from an old methodological paradigm to a new one.

Currently, many scientists believe that a new methodological paradigm is emerging, which in pedagogy is called educology [6]. The reason for the emergence of a new educational methodology, in our opinion, is global factors influencing society.

This is the growth of information singularity, digitalization of society, crisis phenomena in various spheres of human activity, the competitive struggle of humanity for resources, including information and intellectual ones.

In these conditions, it is necessary to look for ways to improve the administration of educational and training systems, in particular university departments. They are the basic units of the university [7] and must ensure the efficiency of its functioning.

Research conducted in [8] showed that a university department as a system is difficult to attribute to any known class of systems. It has a number of specific properties and can be characterized as a multi-channel, very complex, combined, organizational and technical dynamic system, functioning cyclically on the basis of human natural intelligence.

To the above characteristics, it is important to add the properties of reflection, since it ensures the ability of a person, both teacher and students, to highlight, analyze and relate their own actions to the subject situation, while acquiring the appropriate competencies.

Let us subject this system to a comprehensive analysis, taking the systems approach as a basis, and formally write down its results in set-theoretic language.

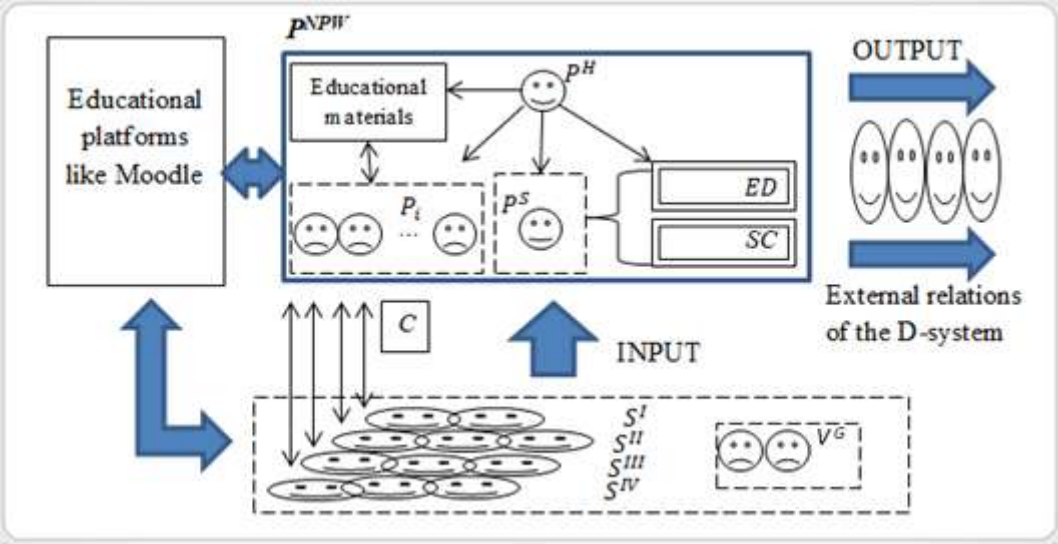

Fig. 1. Extremely generalized *D*-system

Structural analysis

Using structural analysis methods, the relationships and strength of connections between the subsystems and structural elements of the university department, which is presented in the form of a *D*-system, were identified. In Figure 1 shows the main connections and relationships between the elements of the studied *D*-system, the structure of which is determined by the Law on Higher Education of Ukraine. [7].

In Figure 1 the following designations are adopted:

$\boldsymbol{P^{NPW}} = \{\boldsymbol{P^H}, \boldsymbol{P_i}, \boldsymbol{P^S}\}$ – permanent staff of the department – variety scientific and pedagogical workers, where $\boldsymbol{P^H}$ –the head of the department, $\boldsymbol{P_i}$ – full-time scientific and pedagogical staff ($\boldsymbol{i} > 5$), $\boldsymbol{P^S}$ – support staff (employees of the educational laboratory *ED* and scientific laboratory *SC*, respectively);

$\boldsymbol{V^G}$ and $\boldsymbol{S} = \{\boldsymbol{S^I}, \boldsymbol{S^{II}}, \boldsymbol{S^{III}}, \boldsymbol{S^{IV}}\}$ – variable composition of the department, where $\boldsymbol{V^G}$ – graduate students of the department, $\boldsymbol{S} = \{\boldsymbol{S^I}, \boldsymbol{S^{II}}, \boldsymbol{S^{III}}, \boldsymbol{S^{IV}}\}$ – students of different years;

C – cognitive relations.

The structures of scientific and educational laboratories are not considered in this work due to the wide variety of computing tools and networks, as well as instruments and special devices used in the educational process.

Note that the organizational structure of the *D*-system is characterized by a social hierarchy that implements the principle of sub tion $P^H \xrightarrow{F} (P_i, P^V, P^S)$. Here *F* is a bundle of relations associated with the performance by the head of the department of his functional responsibilities in relation to P^{NPW}. In the structure of the department we will distinguish between "scientific supervisor" relationships. So, for example, a graduate student's supervisor is a professor $P_i^{Pr} \xrightarrow{r} V^G$ or department head $P^H \xrightarrow{r} V^G$. department head $P^H \xrightarrow{r} V^G$. In addition, scientific and pedagogical workers can be students' supervisors in the process of writing dissertations$P^{NPW} \xrightarrow{dr} S^{IV}$.

Important relationships in the structure of the *D*-system that motivate P^{NPW} to perform his functional duties efficiently are career relationships. These can be expressed by a preference tuple (1)

$$P^{as} \succ P^{t} \succ P^{st} \succ P^{ap} \succ P^{Pr} \succ P^{H}, \quad (1)$$

where the superscripts denote *as* – assistant; *t* – teacher; *st* – senior teacher; *ap* – associate professor; *Pr* – professor; *H* – head of department.

It should be noted that the above relationships are realized and updated thanks to the presence of natural intelligence among the elements $P^{NPW} = \{P^H, P_i, P^S\}$. This fact, when analyzing the elements of the *D*-system, leads to the consideration and study of the postulates of personality theory [9]. These include:

- Axiological Self – a system of value orientations of the individual;
- Vital Self – a system of basic vital functions of the individual;
- Reflexive Self – a system of connections between basic values and the main vital functions of an individual;
- Reflected Self – a changeable system of internal sociogenic deterministic control of behavior.

These postulates and extensive pedagogical experience allow the authors of this work to interpret educational activities as a set of relationships between the elements of the structures of constant and variable composition of the *D*-system as cones $N^{\Delta\uparrow}$ and cocones $N^{\nabla\downarrow}$ of morphisms, respectively, where $N = \{N^{\Delta\uparrow}, N^{\nabla\downarrow}\}$. These relationships implement the well-known didactic principle of "many-many" teaching.

An important concept in personality theory is the concept of "target structure". In our opinion, the success of the professional activities of P^{NPW}, as well as the effectiveness of the functioning of the entire *D*-system, depends on the balance of their educational goals. In the structure of professional activity of P^{NPW}, three types of target settings are conventionally distinguished – free, deterministic and stochastic. By deterministic goals we mean goals that are achieved by P^{NPW}, with strict fulfillment of their functional duties: teaching classes, participating in department meetings, participating in methodological seminars, etc.

By free goals we mean goals that a person achieves or does not achieve in his creative activity: writing a scientific paper, preparing for classes, etc. Stochastic goals are goals that are not included in the structure of educational goals of P^{NPW}, for example, career guidance work, organizational work [10].

Practice shows that with a large classroom load, the implementation of the total number of free and stochastic goals is reduced to a minimum.

Conversely, a small classroom load of $\boldsymbol{P^{NPW}}$ leads to an increase in the of realized free and stochastic goals. It is natural to assume that a large number of realized free goals with a small number of realizations of stochastic goals leads to the actualization of career relationships (see formula 1).

Space-time analysis

The space-time analysis of the *D*-system concerns only its basic elements P^{NPW}. Let us analyze a typical educational process from the point of view of achieving pedagogical mastery P^{NPW}. In the work [10], the concept of "time horizons of purposefulness P^{NPW}" is introduced, which refers to time periods located in the future, according to which the actualization of a certain set of educational goals is predicted. In this case, 4 conditional time periods are distinguished $\{t_1^g, t_2^g, t_3^g, t_4^g\} \in T^P$ in professional activity P^{NPW}.

Let's project the relationships of P^{NPW} career growth into selected periods of their professional activity

$$P^{as}(t_1^g) \succ P^t(t_2^g) \succ P^{st}, P^{ap}(t_3^g) \succ P^{Pr}, P^H(t_4^g). \quad (2)$$

In the initial period of their professional activity $t_1^g = 2$ years, as a rule, assistants accumulate knowledge on educational material. They have little knowledge of the methods and criteria for measuring the degree of achievement of educational goals, and also find it difficult to independently assess their knowledge of the content of the academic discipline.

The second period of professional activity of P^{NPW} is characteristic of P^t. They are characterized by the desire to realize the accumulated experience, as well as the desire to improve the level of their scientific and methodological knowledge.

Based on the experience gained, there is a need to adjust deterministic goals, update free goals related to preparing a teacher for classes, and update goals related to solving creative scientific and methodological problems. During this period of time, the teacher has the ability to quickly prioritize in the actualization of free and stochastic goals.

The third and fourth horizons of determination t_3^g, t_4^g are typical for experienced P^{NPW} holding the positions of associate professors and professors. They strive to make a certain contribution to the scientific and methodological base of the *D*-system, establish themselves as a qualified teacher and pass on their teaching experience to novice teachers.

Pedagogical experience shows that the goals of the time horizon t_4^g are achieved only by some teachers. The main goal of this time horizon is to become an expert teacher.

By an expert teacher we mean a teacher who has an academic degree of Doctor of Science and (or) the academic title of professor, who has extensive methodological experience and extensive methodological knowledge.

Functional analysis

Reference literature classifies the work of a teacher as mental, intellectual work, which includes such mental procedures as analysis, generalization, decomposition, aggregation, etc. In our opinion, the functional responsibilities of P^{NPW} have become significantly more complicated due to many restrictions and requirements.

On the one hand, the activities of P^{NPW} are limited by the Law on Higher Education, educational standards, orders of the Ministry of Education and Science of Ukraine, the University Charter, orders of rectors, many instructions, etc. On the other hand, the requirements for the quality of training of undergraduates, graduate students and teaching activities in general are increasing. In the professional activities of P^{NPW}, contradictions arise both at the individual (subjective) level and at the level of the *D*-system.

The question arises: how to increase the productivity and efficiency of teaching activities and the *D*-system as a whole?

Obviously, the answer to this question must be sought in the digitalization of society, the saturation of the education system and, in particular, the *D*-system with IT technologies. Currently, a huge amount of theoretical work has been done on the automation of learning processes [11, 12, 13]. In addition, the results of theoretical research, in particular modeling the elements and processes of student learning, are presented in a series of monographs [14, 15, 16], etc.

However, none of the above works contains an answer to the question: what specific tasks in the learning process will the teacher effectively solve, relying on his natural intelligence, and which ones can be "assigned" (delegated) to models endowed with artificial intelligence?

And another question: which of (2) builds models of their intelligence? Practice shows that models of their knowledge in various forms, as a rule, can be built by P^{ap}, P^{Pr}, P^{H} who are located on the third and fourth time horizons of determination t_3^g, t_4^g. We are talking about creating paper versions of knowledge – these are high-quality teaching aids and textbooks, as well as electronic versions – electronic textbooks, expert teaching systems and programs that can be used in the development of syllabus-oriented teaching technologies, the model of which is shown in Figure 2.

It is shown here that P^{ap}, P^{Pr}, P^{H} build models of their professional knowledge in the form of some educationally oriented program that occupies strictly defined places in the metamodel of the knowledge base in the specialty. Let us explain what has been said with another drawing (see Figure 3). Here we present a model, which is a body of knowledge of P^{ap}, P^{Pr}, P^{H}, united by logical connections in accordance with the structural and logical diagram of the specialty (see bottom of Figure 3). In turn, the knowledge of each of P^{ap}, P^{Pr}, P^{H} represents a network model of an academic discipline. In artificial intelligence theory, such networks are called hierarchical semantic networks, which form the basis of large knowledge bases and are considered the most difficult to implement

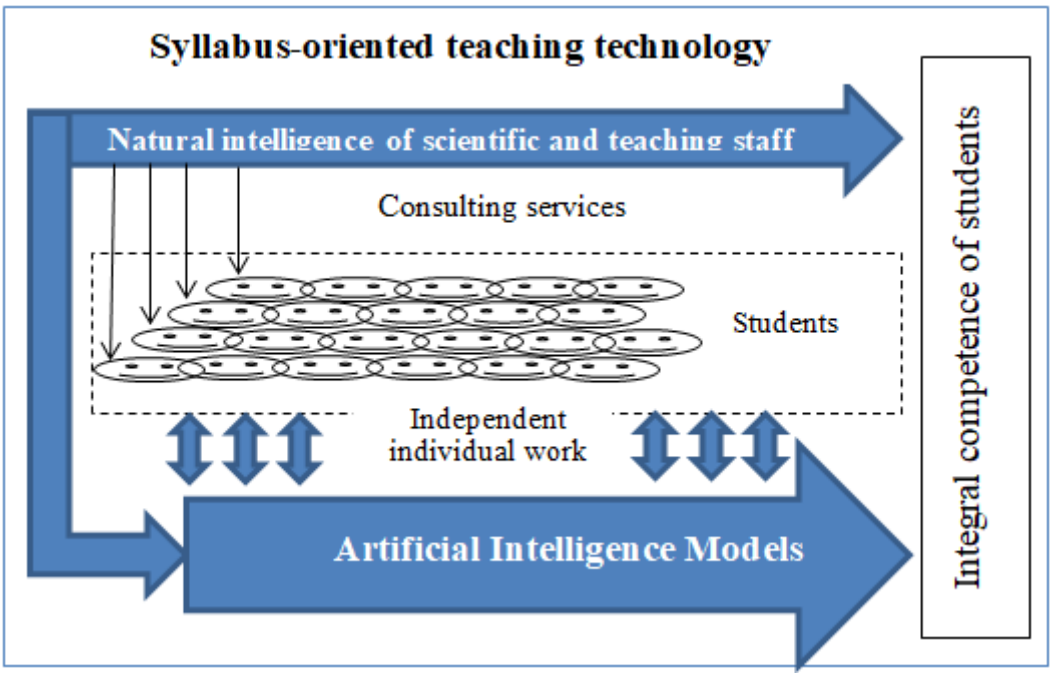

Fig. 2. Extremely generalized model of syllabus-oriented learning technology based on integrated intelligence

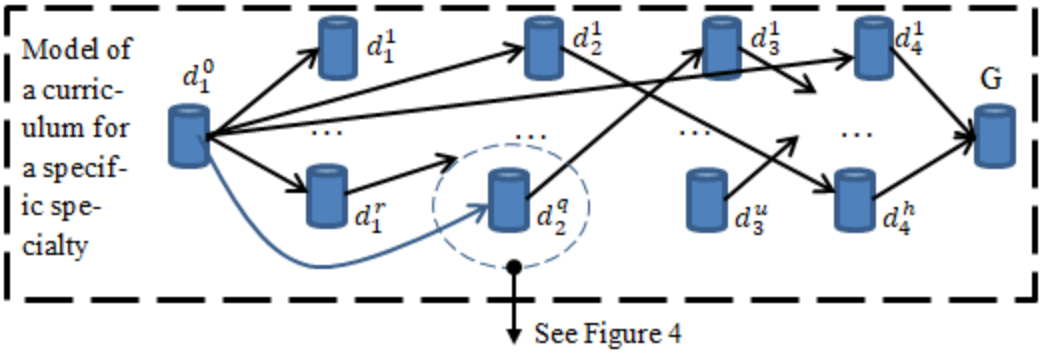

Fig. 3. Model for representing educational knowledge in a specific specialty by a hierarchical semantic network

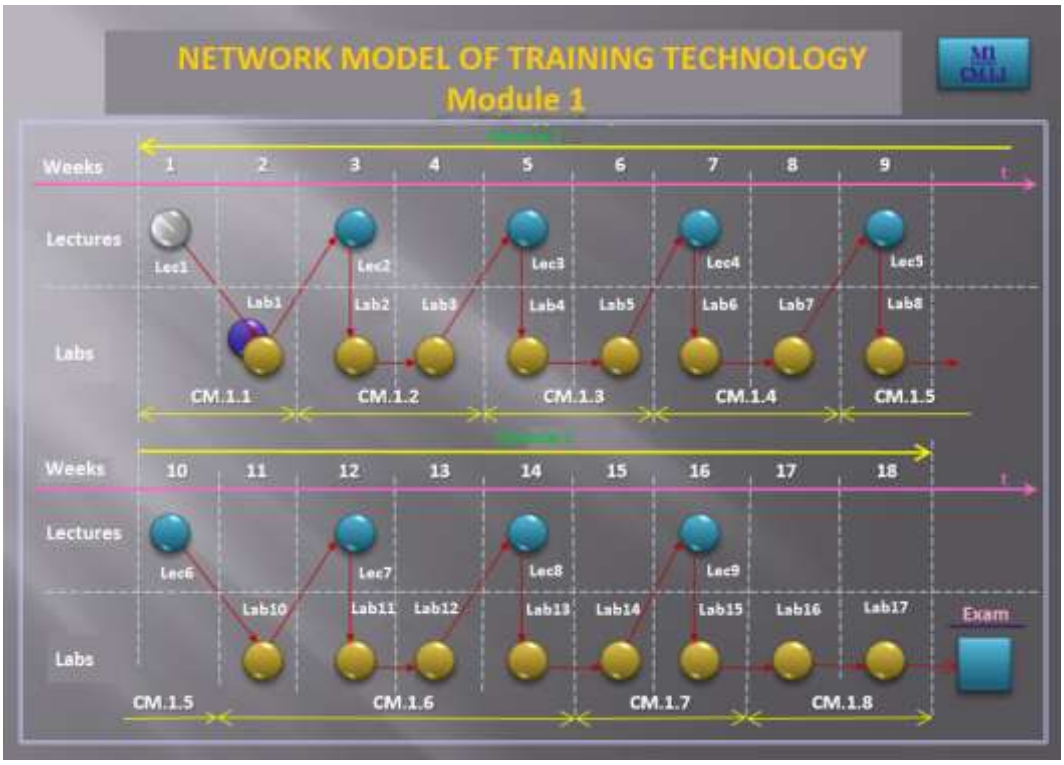

Fig. 4. Fragment of the semantic network of an academic discipline d_2^q

Legend in Figure 3:

d_1^0 – discipline "Introduction to the Specialty";

d_1^1 … d_1^r – disciplines of the 1st year of study;

r – the power of the complex of disciplines of the 1st year of study;

d_2^1 … d_2^q – disciplines of the 2nd year of study;

q – the power of the complex of disciplines of the 2nd year of study;

d_3^1 … d_3^u – disciplines of the 3rd year of study;

u – the power of the complex of disciplines of the 3rd year of study;

d_4^1 … d_4^h – disciplines of the 4th year of study;

h – the power of the complex of disciplines of the 4th year of study;

G – final qualifying work.

A prototype of such a knowledge base has been implemented and partially tested. This is a special program written in Delphi. Its interface is shown below in Figure 5. This shows the curriculum model for the Applied Linguistics major.

It is stylized as a mountain route, where each point on the route corresponds to an academic discipline. It's designed for student users and teacher users.

At the user's request, it shows a logical connection with other disciplines, i.e. imitates the structural and logical diagram of the specialty.

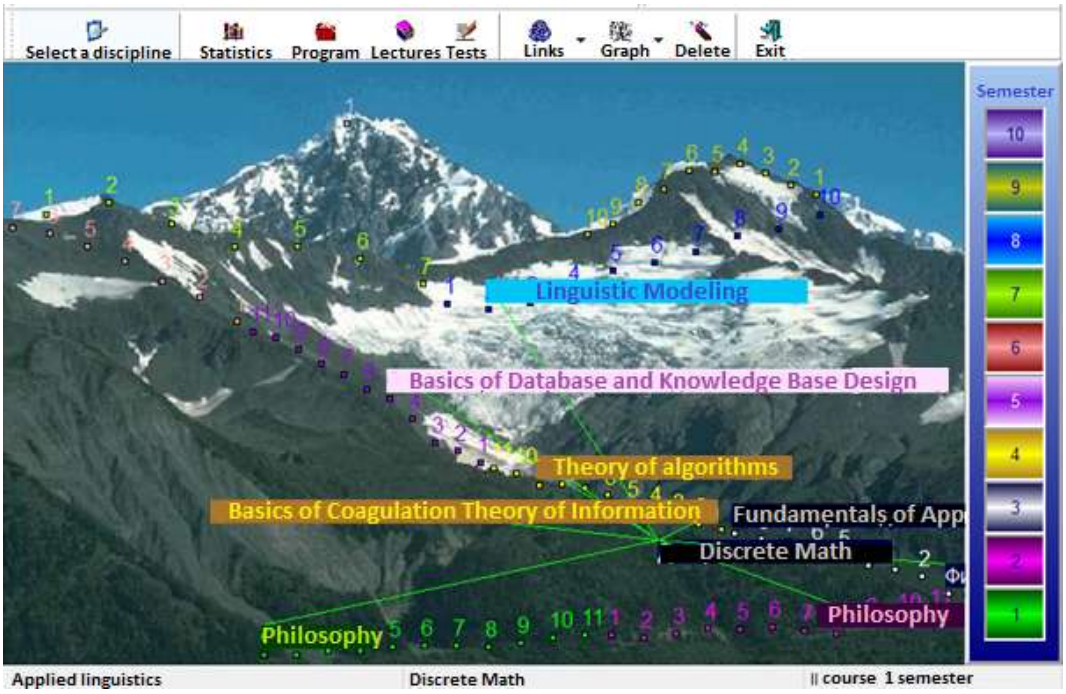

Fig. 5. Appearance of the knowledge base interface for the specialty "Applied Linguistics"

On the toolbar there are buttons "Select discipline", "Statistics", "Program", "Lectures", "Tests", etc., providing the following functionality.

For scientific and pedagogical workers:

- develop the content of the discipline in the form of work programs, lectures and media files, in which teachers briefly provide annotations on the discipline being studied;
- develop tests to test students' knowledge based on the criteria of response time to questions, correctness and complexity of questions asked;
- based on statistics of students' academic work, as well as grades obtained as a result of testing, develop appropriate comments (implement the principle of teaching students according to individual trajectories);
- create a list of additional sources of information.

For students:

- independent study of educational material (models of knowledge of scientific and pedagogical personnel);
- testing your knowledge, both based on the materials of one lecture and on the materials of the entire course (models of knowledge of scientific and pedagogical personnel);
- acquisition of special competencies is carried out according to the classical scheme.
- independent study of the senior course discipline, if the statistics and grades of students meet the criteria for an excellent student.

Conclusions

Thus, a detailed comprehensive analysis of the functioning of the department as a complex *D*-system and its main elements, namely scientific and pedagogical workers, allowed us to draw the following conclusions.

Firstly, the modern conditions in which the higher education system operates and develops and, in particular, the department as the basic unit of universities, lead to a rethinking of some provisions related to the use of applied information technologies in universities and university departments.

Secondly, at the first stage of building and implementing a syllabus-oriented learning technology using integrated intelligence, the help of an IT specialist is needed to organize and maintain knowledge models of scientific and technical staff, as well as the specialty knowledge base in general.

Thirdly, when introducing syllabus-oriented teaching technology into the practice of the *D*-system, it becomes possible to shorten the training period for talented students who are able to study independently due to their determination and ability to quickly assimilate new educational material.

Fourthly, with the introduction of *D*-systems into the educational process, scientific and pedagogical workers are freed from routine work by delegating some of the functional responsibilities in the field of educational and methodological work to artificial intelligence. This makes it poss-

ible to effectively redistribute the working time of scientific and pedagogical workers to scientific, organizational and other types of work.

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Комплексний аналіз функціонування кафедри ЗВО як складної системи в сучасних умовах

Анотація. Постановка проблеми. *Завдання створення ефективної системи управління освітою та навчанням актуальне вже понад 20 років. З кожним роком посилюються суперечності між колосальними можливостями цифровізації навчально-виховних процесів та застарілими методами навчання студентів у вищій школі. У цих умовах необхідно шукати шляхи підвищення продуктивності систем адміністрування освітніх та навчальних систем, зокрема кафедр. Саме вони є базовими підрозділами ЗВО та мають забезпечувати ефективність його функціонування.* ***Мета*** *– на основі всебічного аналізу виявити слабкі місця у процесі адміністрування кафедр в умовах інформаційної сингулярності та кризових явищ у суспільстві.* ***Методика.*** *Для досягнення поставленої мети проведено комплексний аналіз кафедри як системи. Застосовувалися структурний аналіз для виявлення відносин та сили зв'язків між підсистемами та елементами кафедри, просторово-часовий аналіз для прогнозування підвищення педагогічної майстерності НПП, функціональний аналіз для виявлення факторів, що впливають на підвищення продуктивності та ефективності викладацької діяльності й роботи кафедри загалом.* ***Наукова новизна.*** *Детальний комплексний аналіз діяльності науково-педагогічних працівників, а також функціонування кафедри як складної системи зумовив переосмислення окремих положень, пов'язаних з упровадженням ІТ-технологій у ЗВО та використанням їх на кафедрах. Результати аналізу формалізовані та подані теоретико-множинною мовою.* ***Практична значущість.*** *Формалізація результатів комплексного аналізу кафедри як системи є основою для інтегрування штучного інтелекту до роботи кафедри ЗВО, що в сучасних умовах необхідно для підвищення ефективності функціонування кафедри, а також якості процесу вищої освіти.*

Ключові слова: *кафедра, структурний аналіз, просторово-часовий аналіз, функціональний аналіз, складна система, формалізація.*

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