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Methodology of creating an educational electronic information environment

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ABSTRACT The article highlights the results of developing a methodological basis for the formation of an educational electronic information environment using an interdisciplinary approach. The paper synthesises the provisions of systems theory, information processes, and the mathematical apparatus of set and graph theory to create a holistic architecture for digital learning. Particular attention is paid to methods of visual and mathematical modelling using the unified UML and BPMN notations, which allow for the formalisation of complex structural-functional relationships and the algorithmisation of educational trajectories. Integration of the "Electronic University" system with external services from well-known digital platforms enables the use of interactive learning tools. The methodology for creating an educational electronic information environment comprises visual and mathematical models, as well as practical cases. Such a combination allows for reducing the gap between the theoretical basis of modelling and the practical implementation of the software complex. The study demonstrates how combining theoretical constructs and modern engineering methods enables the design of adaptive, scalable, and pedagogically effective systems that can be integrated into the global information space.

KEYWORDS Educational electronic information environment, systems theory, information processes, mathematical modelling, graph theory, business process modelling, digitalization of education, individualization of learning, information ecosystem, electronic university

I. INTRODUCTION

The relevance of creating an effective educational electronic information environment stems from the development of information technologies, which enable the implementation of automated, digital processes for distance and blended learning. In addition to the well-known trends in the development of various technological tools, the introduction of an educational electronic space allows us not to stop educational and management processes in crisis conditions (war, epidemics), as well as to introduce electronic communications with stakeholders, invited lecturers from different countries, to make independent learning effective, to implement the principle of "learning throughout life", etc. [1-4]. An analysis of various information sources on the creation of an educational electronic information environment (EEIE) showed that the results of research in this area can be divided into the following groups: pedagogical research on the use of ready-made technologies for digitizing educational and management processes [3;5-7]; research on information technologies for creating distance and blended learning platforms [8 - 10]; creation and research of models of an electronic information space for implementing the concept of "Electronic University" [11]; research into the effectiveness of using information technologies and tools for distance and blended learning platforms. Despite a sufficient number of scientific works on the development of distance and blended learning, the design and implementation of an educational electronic information environment, there is no comprehensive methodology for its creation, which requires new research and the use of tools from the theories of systems, the learning organisation, information, business processes, etc.

The term educational electronic information environment focuses on the processes of learning, the use of electronic tools, and the transmission and receipt of information in a single environment. This definition combines various terms of the same content - educational information environment, corporate learning environment, educational electronic environment, etc.

From the perspective of general systems theory, the educational environment appears as a complex, holistic and open structure, the effectiveness of which is directly determined by the quality of information connections and synergy between its components. The application of the theory of information systems enables us to interpret the educational electronic information environment as an integrated set of technical, software, and intellectual resources aimed at optimising information flows and transforming disparate data

into structured knowledge. The methodological foundation of the study is supplemented by the principles of the theory of a self-learning organisation, according to which an educational institution turns into a flexible system capable of constant self-reflection, adaptation and continuous updating through the accumulation of collective experience of participants. A key aspect in this context is the concept of mirrors, which, in the context of an electronic environment, is implemented through the mechanism of information reflection [12]. Information theory allows us to estimate entropy at both the individual module and the system levels [13-16]. The educational electronic information environment serves as a digital reflective screen, not only accumulating knowledge but also providing learning subjects with the opportunity to observe the results of their own activities in real time and interact with certain participants in educational and management processes. The phenomenon of information reflection contributes to the creation of a virtual duplicate of real educational processes and to the implementation of specific digital operations, in which each user action is accompanied by rapid feedback, thereby intensifying awareness of educational material and the development of critical thinking. At the same time, an analysis of scientific works on the digitalisation of distance and blended learning reveals a fundamental contradiction in the development of such environments: researchers are forced to balance traditional teaching or management methods with modern capabilities for automating and digitalising processes. Using the concept of information reflection in combination with the tools of systems and information process theories allows us to clearly identify priority information in the subject area and ensure its logical structuring. In the context of the transformation of the knowledge society and the digitalisation of the educational space, the university is increasingly viewed not only as an institution providing educational services, but also as a complex socio-economic system capable of continuous self-development, adaptation, and the generation of new knowledge. In this context, it is appropriate to apply the concept of a learning organisation, which allows us to rethink the role of the university in the modern educational and innovative environment [17;18].

A learning organisation is defined as one that systematically creates, accumulates, disseminates, and uses knowledge to increase its own efficiency and competitiveness. The application of this concept to the university is based on the recognition that learning there takes place not only at the level of education seekers, but also at the levels of teachers, administrative staff, and organisational structures in general.

A university as a learning organisation is characterised by institutional mechanisms that ensure reflection on its own experience, analysis of its activity results, and the implementation of changes based on the knowledge gained. Such mechanisms are implemented through education quality assurance systems, internal audit, academic mobility, interdisciplinary interaction, and the use of digital platforms for knowledge management and educational processes. Thus, the educational electronic information environment can be presented as a socio-technical system that integrates educational, scientific and management processes.

Educational activities aim to develop the competencies of education seekers, scientific and research activities aim to create new knowledge, and managerial activities aim to ensure conditions for effective interaction and the development of these processes. The interconnection of these subsystems contributes to the formation of a closed cycle of organisational learning, in which the results of research are implemented in the educational process, and managerial decisions are adjusted based on the analysis of educational and scientific results. Similarly, corporate learning is introduced in enterprises as they implement innovative processes. In their research, the authors consider the educational and managerial processes of a university as an educational institution that has its own electronic platform for blended learning and institution management (“Electronic University”) [11]. But all the proposed concepts can be adapted to a corporate electronic university.

An educational electronic information environment is defined as a set of software and hardware, information resources, digital services, and organisational regulations that ensure the planning, implementation, monitoring, and control of educational activities, as well as related management and business processes. Its functioning is based on the principles of systematicity, integration, openness and continuity of information flows.

From the perspective of a process approach, the educational electronic information environment provides digital support for the main educational processes, in particular, the development and implementation of the university development strategy and its "electronic twin", educational programs, organisation of the educational process, assessment of learning outcomes and their consolidation, academic communication and storage of educational data. Automation of these processes increases their transparency, manageability, and reproducibility, and also creates conditions for personalisation of learning and for the use of data to make informed management decisions.

Along with educational processes, the educational electronic information environment encompasses the university's digital business processes related to student management, financial and economic activities, human resources, document management, and interaction with external stakeholders. Digitalisation of business processes ensures cost optimisation, reduced transaction execution time, and improved quality of educational services.

The integration of educational and business processes within a single electronic information environment forms a holistic model of a digital university, in which information flows serve as the basis for organisational learning and the continuous improvement of activities. Such integration enables the implementation of a closed management cycle, which includes data collection, analysis, decision-making, and evaluation of the results by determining the level of maturity and socio-technicality of the educational electronic information environment.

The scientific works of S. V. Tytenko are based on the development and implementation of a conceptual-thesis model as a fundamental apparatus for the construction of intellectual educational systems. This model is based on the idea of formalising knowledge through a two-level structure, where the first level is represented by concepts as nodes in a semantic network, and the second by theses that record didactically significant statements about these concepts and their connections [19]. This approach enables transforming a poorly structured educational text into a machine-readable knowledge graph, which serves as the basis for further automation of the educational process.

The central role of the conceptual-thesis model is to ensure the adaptability of learning. By analysing the knowledge

graph's topology, the system can automatically generate individual trajectories for mastering the material, considering the prerequisites and the logical sequence of presentation. The model is a tool for objective knowledge assessment, as it allows the automated creation of test tasks in which correct answers and distractors are generated based on semantic relationships between the model's nodes, thereby ensuring high validity of the control measures.

In modern research by the author, the conceptual-thesis model serves as a structured framework that guides large language models, ensuring the accuracy of generated content and preventing factual errors. This allows the creation of dynamic, interactive textbooks, where the content is not only displayed as hierarchical conceptual maps but is also constantly updated and detailed in response to user requests.

The practical implementation of the model is embodied in the architectures of ontologically oriented educational content management systems. The use of a conceptual-thesis approach enables the implementation of complex algorithms to organise didactic units and optimise research-learning interfaces. Such a model is a universal bridge between the pedagogical theory of knowledge structuring and the engineering implementation of high-tech educational platforms that combine graph knowledge bases, mobile technologies, and neural network tools. The electronic learning environment is actively evolving in many universities around the world. Most of them employ the methods of connectivism and constructivism, adapting well-known universal platforms or implementing in-house software solutions. The development of platforms for distance and blended learning also involves introducing various scenarios for implementing educational and management processes. An analytical review of scientific works indicates that fragmentary research in the areas of organisation, information implementation, management, and pedagogical technologies is needed to create an effective educational electronic information environment. The combination of technological, pedagogical, and management methods for training in educational institutions and corporations will allow us to develop a methodology for creating an environment that adapts to users' needs and reflects the organisation's development and its IT environment. Thus, the study "Bridging Web 4.0 and Education 4.0 For Next Generation User Training in ERP Adoption" is devoted to addressing the low efficiency of training users of cloud enterprise resource planning systems [20]. The authors emphasise that traditional personnel training methods do not align with the complexity of modern ERP solutions, resulting in a low level of organisational perception of these systems. The key scientific idea of the work is the synergy of the concepts of Web 4.0 and Education 4.0 to create a transformative learning ecosystem.

The theoretical basis of the study is based on the intellectualisation of human-machine interaction. Web 4.0 is considered not just as an instrumental environment, but as a symbiotic network where the intelligence of the machine and the user act in harmony. In the context of modern management, this means a transition from static instructions to dynamic learning that adapts to each employee's needs. An example of such integration in the article is the use of artificial intelligence algorithms to analyse user behaviors in the system, enabling personalised tips to be provided in real time.

The methodology for the work is based on qualitative analysis, involving expert groups and potential end users. The authors propose an innovative architecture that combines Education 4.0 modules – such as flexibility, personalisation, and immersiveness – with the technological capabilities of cloud management systems. The article describes in detail how the principles of Education 4.0 change the role of the trainer from a knowledge translator to a facilitator who manages the process through simulation sandboxes and applied tests. This allows users to master complex business processes through practical immersion rather than just theoretical study of the interface. That is why business process modelling (and, in our case, educational and management processes) will allow us to increase the use of modern information, management, and pedagogical technologies and to eliminate barriers between complex technology and human perception.

The analysis of literary sources indicates that educational institutions and corporate companies need a comprehensive methodology for creating and using an educational electronic information environment. Such a methodology includes principles, concepts, general and specialised methods for implementing software modules, and libraries of mathematical and visual modelling. This will allow specialists who create and use an electronic learning space to more effectively apply existing e-learning tools and improve their methods and means.

The purpose of the research is to develop a comprehensive methodology for creating an integrated educational electronic information environment based on interdisciplinary methods, mathematical and visual models grounded in systems theory, the learning organisation, the concept of mirrors, and tools of modern technologies for distance and blended learning.

Synergy and improvement of known theories, concepts, methods, and practical tools will enable the development of qualitatively new models of the educational electronic information environment, as well as the strategy and tactics for its implementation in a higher education institution.

II. MATERIAL AND METHODS

To develop the methodology for creating an educational electronic information environment, the theories of systems, information, information systems, information processes, sets, graphs, and mathematical and visual modelling methods were used. The methodological basis for developing an educational electronic information environment is grounded in the fundamental principles of systems theory, which allow us to consider an object as a holistic set of interconnected elements that, through interaction, produce a new synergistic quality. According to the founder of the systems approach, L. von Bertalanffy, systems theory enables the identification of the environment's structure as a holistic set of components, their internal and external relationships, and mechanisms for managing certain processes. The introduction of information and information systems theories enables the optimisation of the environment's architecture for effective reflection, accumulation, storage, and transfer of knowledge, while minimising entropy and information loss. The development of the theory of information reflection enables us to define the concept of mirrors, which involves assessing the extent to which certain business processes are covered within the organisation. For the university, business processes are the educational and management processes for providing distance and blended learning services to certain user groups through various agents in the environment. The use of graph theory is key to visualising and analysing the topology of information flows, where nodes represent structural units of the environment, and edges represent logical and functional

connections between them, which correlates with the concept of human-computer interaction and research on user behaviors in the educational environment.

Mathematical modelling methods create abstract analogues of educational and management processes to predict the system's behavior under the influence of various factors, continuing the development of the principles of cybernetics by S. Bira [21]. Visual modelling, in particular using UML languages, BPWN transforms mathematical models into graphic diagrams, providing a high level of clarity and determinism when designing interfaces and logic of agent interaction in digital space [22; 23]. The combination of these methods forms a comprehensive methodological platform that guarantees adaptability, scalability and a high level of socio-technicality of the educational electronic information environment.

III. RESULTS

A. GENERAL MATHEMATICAL CONTOUR MODELS OF THE ENVIRONMENT

The mathematical model of the educational electronic information environment is a set of sets of contours - functional, management (monitoring and control); implementation scenarios using various modules; motivational and emotional contour, communications and interaction.

$$OEIS = \langle z_p, z_f, z_{r1\dots r2}, z_k, z_m \rangle, \quad (1)$$

where z_p – contour of monitoring and control of the results of current activities; z_f – contours of functionality for carrying out activities; $z_{r1\dots r2}$ – contours of scenarios for implementing activities; z_m – motivational contour of activities; z_k – contour of communication and interaction.

Each circuit can be represented as a collection of sets of agents (users or software modules), electronic static and dynamic resources, and communications.

$$Z = \langle A, ER, B \rangle \quad (2),$$

where A is the set of agents (software modules and users); ER is the set of electronic resources; B is the set of interactions between agents. The interaction B_{ij} with the defined vectors describes the nature of the information interaction of agents A_i and A_j $(i \neq j, i = 1, \mathrm{N}, j = 1, M)$.

The concept of mirrors can be implemented as a formula for determining information perception, presentation, processes, process indicators, the level of fullness of electronic resources, and the level of information reflection by the agent.

$$J_{spr} = R_k(J_p) = R_{ka}(M_{spr})M_{pr} \quad (3),$$

where J_{spr} – information perception; J_p – submission information; J_{sp} – process information; M_{spr} – perception metrics; M_{pr} – process metrics; R_k – relative fullness of electronic resources; R_{ka} – relative perception (reflection) of information by the agent [12].

The information vector of perception can be represented as a Gaussian integral covering the vector of information flows per area of the environment

$$J_{spr} = \oint_S R_k O dS = \oint_S O_{spr} dS \quad (4),$$

where $O_{spr} = R_k O$ – reflection intensity vector; O_{spr} – vector of coverage of educational and managerial activities, and its reflection in users' perceptions.

If we use the Gaussian integral to estimate entropy, it serves as a measure of uncertainty because it has maximum entropy. In the context of reflection, by determining entropy, we can identify the point at which information for learning becomes noise. For the main page of the learning management system, the level of entropy is not as important as in the modules for learning - the navigator, the testing system, and the system of communications with the teacher.

To assess the coverage of the processes required to create an effective electronic educational information environment, compile a list of all processes, determine their priorities, and assess the extent to which they can be automated. Such data will serve as the basis for assessing the maturity and socio-technicality of the "Electronic University" system. The maturity level is defined as the sum of all implemented processes, taking into account the automation priority and completeness coefficients.

To determine the level of socio-technicality of the system, it is necessary to consider the educational information electronic environment as a component of modules that automate educational, management, and information flows, and to consider the social impact of each process (processes that interact with users will have a higher priority).

Considering that such an environment is designed for different user groups (teachers, students, managers, employees), for practical use, it is advisable to represent the reflection information vector as the sum of automated and digitised processes for the activities of representatives of each target group.

It is advisable to choose different models for each target group. For example, the modernised SAMR model allows for systematising the processes of using technology in two directions - improvement and transformation [24].

Substitution – introduction of automated processes as a replacement for traditional ones.

Augmentation – improvement of processes with functional improvement.

Modification – creation of new processes, modernisation of existing ones.

Redefinition – fundamentally new processes that could not be implemented before.

The modified SAMRK model can be used to assess the maturity and socio-technicality of the educational electronic information environment. For this, the contours of the environment design are considered. Among them, the strategic contour – K_{str} – corresponds to the IT strategy and the creation of an electronic university based on a defined information environment (a set of modules and defined processes); the implementation contour – K_{real} – corresponds to a set of modules for implementing automated and digital processes.

$$OEIS_{pr} = \langle K_{str}, K_{real} \rangle \quad (5).$$

Such models estimate the number of automated and digital processes at each level, accounting for intensity coefficients. Mathematically, such a model, estimating the overall level of socio-technical S_{ozt} in the implementation of processes, can be represented as the sum of the product of the number of

processes, the intensity coefficient, and the automation completeness coefficient.

$$S_{ozt} = \sum_i^n k_i * k_p * k_a \qquad (6).$$

where groups of processes from i to n are defined with intensity coefficient k_i, automation completeness coefficient Ka and number of processes k_p. The proposed socio-technical indicator can be used to compare the system's socio-technical state at different stages of its life cycle and with other similar systems.

B. GENERAL VISUAL MODEL OF THE EDUCATIONAL ELECTRONIC INFORMATION ENVIRONMENT

Fig. 1 presents a General visual model EEIE.

The visual model allows you to determine the main types of processes: educational, supporting scientific and methodological activities, and managerial.

The assessment of the system's socio-technical nature must be carried out for the total number of priority automated processes and for each individual direction, contour, and service.



Figure 1. General visual model EEIE

C. SEPARATE SERVICES AND INTERACTION

The proposed methodology involves creating a holistic web-based information ecosystem, operating each service separately, and using specialised technologies for learning, communication, and interaction, including a web environment, mobile applications, and data transfer to and from external information sources. The system allows you to create a learning environment by implementing unified navigators for the discipline's educational resources and by integrating with Google and Microsoft cloud environments. There is also the possibility of storing methodological and scientific works in a personal repository, with metadata used to generate reports and lists and to monitor teacher activity. To assess applicants' success, a testing module and an automated dean's office system are used. Groups of students are formed based on data from the Unified State Electronic Database on Education (EDEBO). Separate services allow you to manage document flow and monitor changes to educational programs. The motivational and emotional circuit is supported by gamification modules, including monitoring students' and teachers' activity levels, receiving messages, and joint interaction in the forum.

Figure 2 presents a general visual model of the interaction among various services via the system databases and external information sources to maintain data reliability.

Such integration allows reducing the influence of the human factor in data generation and using external cloud services.

The introduction of artificial intelligence technologies allows you to increase the level of socio-technicality of the system by introducing a new group of educational processes, as well as demonstrating to students a scenario of the virtuous use of artificial intelligence by teachers to control knowledge, generate new ideas in the forum through a discussion with an AI agent.

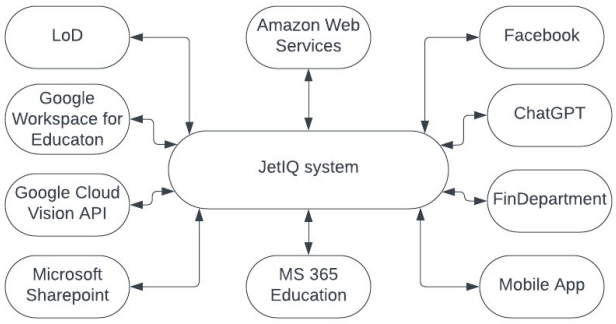


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D. LIBRARY OF VISUAL MODELS FOR CREATING AN ELECTRONIC UNIVERSITY

An electronic university is an educational institution that uses modern information and communication technologies to provide educational services in a distance and blended format, using network electronic resources to support scientific, methodological and managerial activities, network interaction of all participants in educational and research processes, and has external electronic resources for interaction with other universities, enterprises, research institutions, freelancers, etc.

The basis of an electronic university is an electronic educational information environment, which is based on an information ecosystem and allows providing educational services in a distance and blended format, supporting

methodological, scientific and managerial activities of the university and has connections with a network of scientific and research organisations, social professional networks and educational platforms [12; 25; 26].

Technologically, such an ecosystem is a web portal consisting of:

a learning management system,

a system for supporting methodological, scientific and managerial activities,

an external official website of the university, special websites of research projects, websites of departments and websites of scientific publications,

a data exchange system with state education databases,

a data exchange system with professional social networks and open electronic educational platforms.

An electronic university is a comprehensive system for integrating information technologies, organising management, and introducing modern methods of teaching and conducting scientific research to achieve a sufficient level of quality in higher education. To date, the JetIQ VNTU information ecosystem is the basis for IIEI, where more than 8,000 users work; all defined system contours have been implemented; more than 54,000 educational materials have been created; and more than 8.5 thousand test tasks have been completed since the beginning of the academic year. Figure 3 shows a screen view of a working system for managing student and teacher cabinets and special services modules.

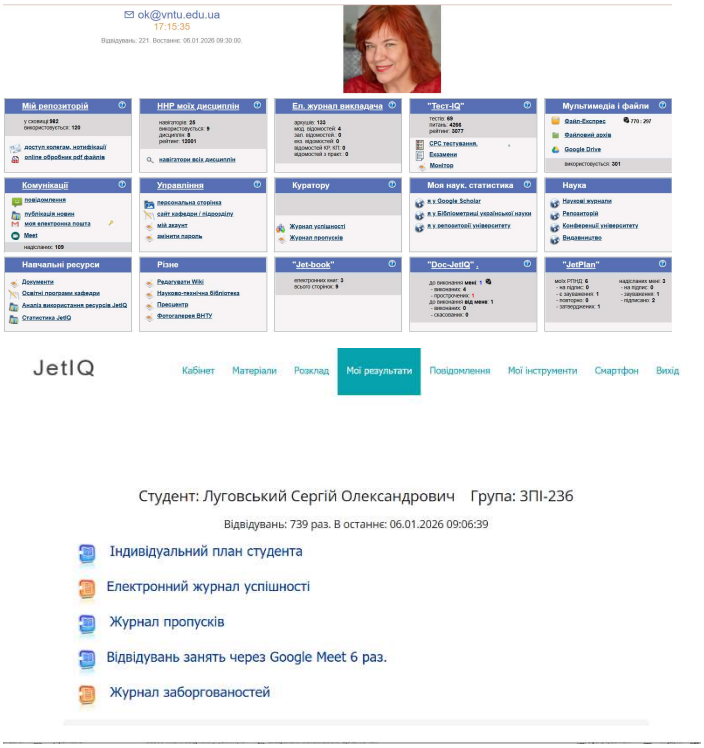


Figure 3. Teacher`s and student`s working spaces

The proposed methodology is adaptable for different educational institutions and corporate learning environments. But the general principles remain the same - the principle of multi-user and reusable use of information; a human-centred approach; process optimisation.

Creating a library of models will allow management and developers of educational institutions and corporate services to use basic models to build an educational electronic information environment. The library should consist of the main clusters - educational, support for methodological and scientific activities (auxiliary), and management processes. For example, in educational processes, the “Automatic Trajectory” model can be used, which includes a route of transitions between modules and definitions of points at which the intervention of a teacher, an administrator, or specialists from the dean's office or services is necessary. Also important is the “Digital Trace of Learning” model, which considers student activities converted into points, activity assessment, and the admission threshold, among other factors.

Additional models support AI technologies, such as “Smart Tests” and “Forum Discussion.”

Auxiliary processes allow you to record scientific and methodological publications for teachers, maintain statistics of professional activity indicators, and automate the creation of methodological materials. For example, the “JetPlan” model is a template for the automated creation of a work program and syllabus, from content generation to the collection of signatures from responsible persons and their upload to the repository.

The cluster of management processes comprises training management procedures (electronic dean's office), departmental (divisional) management of electronic resources, and university management through a document management system and an event calendar.

E. ASSESSMENT OF THE LEVEL OF SOCIO-TECHNICALITY OF THE JETIQ, SEL, AND SOCRATES SYSTEMS

Table 1 presents the calculation data, including expert assessments.

Table 1. Expert assessments of EEIE characteristics

Process groups	Socrat	SEL	JetIQ
1.Functional educational processes	5	5.75	9
1.1.Access to information resources	6	4	8
1.2. Access to tests	8	6	8
1.3.Access to learning outcomes	8	8	9
1.4.Communications in education	5	5	7
2.Electronic Dean's Office	8	7	9
3. Reporting	3	4	8
4.General communications	3	5	5
5.Integration with external resources	3	4	6
6.Document management	2	7	3
7.Emotional circuit	1	1	3
8.Brand presentation	2	3	4
9. Mobile applications	0	2	4
10. AI	0	0	2
Total	54	61,75	85

The obtained experimental data evaluate the functionality of the systems and the level of their development in terms of the defined modules, contours, and socio-technical characteristics (communication, level of gamification, integration, etc.).

IV. DISCUSSION

The results of the study demonstrate that creating an effective educational electronic information environment requires a shift from isolated digital tools to a holistic socio-technical ecosystem. The proposed methodology allows you to bridge the gap between the theoretical basis (systems theory, the concept of mirrors, graph theory) and practical engineering implementation using business process modelling in UML/BPMN notations and modular web integration.

The application of systems, information, and organisation theories allowed us to consider the educational environment not simply as a repository of educational materials, but as an open socio-technical system capable of self-organisation. The limitations of the proposed methodology are the need to create an integrated environment of existing technological elements (original or universal) and special ones created for a specific organisation.

The improvement of the modified SAMR model provided a quantitative mathematical framework for assessing the maturity level and socio-technical index of educational and management processes. Comparative evaluation of three educational systems (Socrate, SEL, and JetIQ VNTU) illustrates the advantages of a comprehensive ecosystem approach and the possibility of adapting the general methodology to the implementation of an educational electronic information environment in a higher education institution and to its integration with various technological platforms.

The created library of visual models can be used both by higher education institutions and adapted by corporate companies. For further research, it is advisable to actively develop improvements to the information ecosystem "Electronic University" using artificial intelligence tools. In addition, it is advisable to form improved models for mobile and microlearning.

V. CONCLUSIONS

The proposed models, implemented software modules, and evaluation of the socio-technical nature of the system confirm that the effectiveness of creating an educational electronic environment directly depends on the depth of methodological processing of its components. The application of theories of systems, information, and information processes enabled us to define the environment as a complex, dynamic object that requires clear mathematical determination. It was established that the use of BPMN methods is important for eliminating the gap between pedagogical requirements and their technical implementation, thereby ensuring high accuracy in modelling subject interactions. Mathematical modelling confirmed the viability of the proposed approaches, providing tools for verifying the system's logical integrity, evaluating socio-technical indicators, and assessing entropy. The results of the work provide a reliable basis for further practical development of intellectual educational platforms focused on the individualisation of learning and the automation of management processes in higher education.

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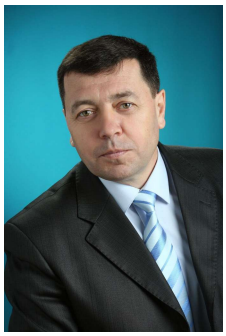
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