Automation of Educational Activities within the OSTIS Ecosystem

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***Abstract*—An analysis of the need for a comprehensive restructuring of the education system, taking into account the requirements of the digital economy, is presented. The ways of solving some problems of the implementation of the educational process at the level of general school education are determined. A semantic approach to building a complex of intelligent learning subsystems including teaching, assisting learning and analytical to accompany the learning process ones within the framework of the OSTIS ecosystem is proposed.**

***Keywords*—intelligent learning systems, semantics, OSTIS ecosystem, knowledge processing.**

I. Introduction

In the context of the transition to the information society and the comprehensive digitalization of all areas of human activity at its various levels, highly qualified personnel are of the greatest value. The volume and level of requirements for the presentation and use of information in all spheres of life is increasing, which entails the inevitable active involvement of professionals in the process of continuous education. A modern person in the information society must be able to adapt to rapidly changing information flows. The formation of such skills is the main task of every educational institution, including universities, which in modern conditions are subject to increasingly stringent requirements. This applies to both the level of teaching and the level of organization of educational activities. Today, the organization of educational activities in schools and in secondary specialized vocational, higher educational institutions largely determines the level of development of the state. Therefore, we can fully explain the great interest in the use of information technology in order to increase the efficiency of this activity. However, despite the rather active research carried out in this direction, it is too early to say that the use of information technology has significantly increased the effectiveness of educational activities. There are many reasons for this. Among them there are both objective technical, methodological reasons, as well as reasons of a purely organizational, administrative nature. These reasons include:

- lack of a systematic approach to the selection of the main objects and processes for automating the activities of educational institutions, including higher ones;
- a small number of viable technologies for the integrated development, implementation, operation, maintenance and evolution of educational automation tools;
- natural social resistance, conservatism that impedes the comprehensive automation of the educational process.

II. Current approaches to the educational activities automation

Automation of educational activities requires an integrated approach, taking into account the peculiarities of educational work at all stages of education, from elementary school to graduation from the magistracy, and possibly further, when obtaining higher qualifications in graduate school. This approach certainly requires the use of existing ones, as well as further development and widespread use of methods and tools of artificial intelligence, and related disciplines. Work in this direction has been carried out by various groups of researchers for more than 30 years. Research is being carried out on the theory and methodology of distance education, new approaches to the development of distance and open education are proposed, based on the ideas of organizational design and reengineering of organizations, methods of knowledge engineering and the theory of agents, models of multi-agent systems and virtual organizations [1]–[7].

A number of authors identified and studied the main classes of systems and technologies needed to create virtual departments of universities and universities in general. Particular attention of researchers is paid to the problems of symbiosis of network and intelligent technologies, for example, models of intelligent learning systems based on multi-agent technologies [8], [9].

One of the current trends in the development of applied intelligent systems (IS) is the implementation of ISs that can not only solve problems from the relevant

subject area, but also train the user in knowledge and skills from this subject area. At the same time, when developing modern computer learning systems (CLS), it became necessary to use methods and tools of artificial intelligence, which led to the emergence of a new class of CLS - intelligent learning systems. At present, due to the growing requirements for systems of this class, the problem of developing The intelligent learning systems have to become relevant, which can be characterized by the following features they should provide:

1) processing large volumes of complexly structured information of various types;
2) flexibility and easy modifiability of the system;
3) integration of various models and mechanisms for solving problems;
4) support for various models of learning and user interaction management;
5) integration of various software systems within one system and management of their operation and interaction;
6) wide use of multimedia tools;
7) work in real time.

Currently, there are CLSs in which these problems are solved with the elaboration of only some individual issues. This is due to the fact that it is not easy to solve all the problems in a complex by the currently existing information and intellectual means. The peculiarity of the implementation of the learning process in ILS is that, in addition to representing and processing knowledge about the subject area, the system must contain information about its users, be able to process it and thus adapt to the individual characteristics of each specific user [10]. In addition, one of the most important issues in the design of a learning system is the management of a dialogue with a user (usually untrained in computer technology). User interaction, in contrast to the interaction of subsystems in a computer system, is a more complex process, since it contains an element of unpredictability.

Consider the features inherent in the initial stage of education - general secondary education. School education is an initial, but very important stage that shapes the entire further development of an individual's education. If schooling is too low, then no further steps will fix it. It is impossible to get a good engineer out of an illiterate, unprepared person. If there is no knowledge base, then it is impossible to build a knowledge base of a higher level. Therefore, we will begin our consideration of the issue of education with school education, especially since many problems and issues that arise in the field of education at higher levels coincide with the problems of school education, or are their consequences. The purpose of education is not only and not so much to expand the horizons and knowledge of the student, the main task is to help him decide on the choice of a field of activity according to his abilities and the needs of society.

An integrated approach to the formation of a strategy for the intellectualization and digitalization of this stage of education requires an analysis of all aspects of education - academic disciplines, pedagogical technologies and methods, psychological characteristics of children of different ages, from primary school students to graduates, organizational features of the educational process, technical equipment of educational institutions, the capabilities of telecommunication networks etc. Such an approach should provide a deep modernization of school education based on the use of artificial intelligence technologies, data and systems analysis, multi-agent technologies, synergistic approaches, modeling, ontologies and semantic technologies. The latter play a special role in the formation of student knowledge at all stages of education. It is imperative to take into account the individuality of the student when choosing pedagogical methods and technologies, which will make it possible to find the right approach to the effective teaching of students with varying degrees of preparedness for the perception of certain disciplines [11].

The main task of the learning intellectual system is to explain, teach and continuously unobtrusively control the process of human learning. Here, a special role is played by semantic intelligent systems that use semantic relationships. Semantic intelligent systems allow, on the one hand, to speed up the process of obtaining knowledge based on obtaining instant access to a huge information field, and on the other hand, intelligent systems should help choose the best learning path, the path along which complete knowledge will be obtained in the shortest possible time.

The socialized characteristics of the quality and quantity of knowledge of graduates of various educational institutions include:

- competencies – a combination of knowledge, skills and experience necessary for the high-quality performance of tasks;
- breadth of knowledge – a set of knowledge from various fields that can complement each other and form a single picture of the world around;
- depth of knowledge – a characteristic showing the extent and the level of complexity of a person's knowledge on a particular issue or phenomenon. For a correct construction of the educational process at a particular level, it is necessary to specifically outline the set of knowledge that a graduate must possess in a particular academic subject;
- stage of education - an independent completed stage of training and education of the education system;
- academic subject - a system of knowledge, skills and abilities selected from a specific branch of human activity.

III. Organization of the educational process

An important task in organizing an effective educational process is to fulfill the requirement that the curricula of each year of study in subjects complement and expand, and not duplicate the knowledge gained in previous years of study. Curricula in subjects and the learning process itself must comply with certain principles (rules, requirements), which will be discussed below.

When compiling curricula, it is necessary to take into account the relationship between various academic disciplines. Knowledge gained in one academic discipline is used in the study of other disciplines. At the same time, the use of knowledge gained in other subjects allows one to consolidate this knowledge. For example, the use of knowledge about trigonometric functions, projections, vectors in solving physical problems allows one to consolidate, deepen and substantiate this knowledge obtained from mathematics.

Consideration of new material, its development in the framework of solving problems, should contribute to the repetition of previously covered material both in this and other related subjects. At the initial stage, tasks are given directly on this material (for example, on the application of a certain formula). For real knowledge of the topic, one must be able to solve problems, in the solution of which it is necessary to use, along with the material of the topic being studied, the knowledge obtained earlier in the study of other topics within this or other subjects.

Consideration of phenomena and laws studied in various sections of educational subjects (regardless of the time of study) at each stage must be complete and cannot be incomplete due to the fact that students do not have any preliminary data. It is also necessary to take into account the consistency and connectivity of the acquired knowledge so that knowledge does not turn into a set of fragmentary information and definitions that require banal memorization. Logical comprehension of the material, building connections of this material with the available knowledge and the surrounding reality are the main components of individual experience. Knowledge appears in the form of concepts and relations between them, as well as judgments and conclusions of the student derived from them. It is such knowledge in the form of skills and abilities that is best stored in the memory of the student.It is necessary to adjust the programs for studying disciplines for the timely use of knowledge in the study of other disciplines.

It is also necessary to consider the issue of filling the content of educational material on each topic in each individual discipline. It should be borne in mind that there are certain restrictions both in complexity and in the volume of new material that a student can perceive in the time allotted for this, in order to avoid overloads that may adversely affect his health. Topics that are displayed in the physical and information space around us due to their vital relevance are mastered most effectively. Topics that do not find reflection in the environment and are not required to obtain the necessary life skills should be derived from the compulsory school curriculum material and given in the most compact form at the familiarization level. Satisfaction of educational programs and the very process of teaching these principles contributes to the fact that various disciplines will form comprehensive knowledge about the world around them.

When considering issues related to education, one cannot ignore the aspect related to the individuality of each student. Each student has abilities and predispositions for certain subjects. Taking into account these factors ensures the maximum possible disclosure of the creative potential of each person. The development of these abilities and the preparation of schoolchildren for the choice of professional activity in later life should be served by additional and optional education. At the level of such education, it is possible to implement a more personalized approach to each student, in which it becomes possible to fully reveal the creative potential of each. At the same time, it is necessary to give more extensive and in-depth knowledge in the chosen disciplines. Also, the issues of organizing secondary education must be closely linked with the organization of education at subsequent levels. The foundation of knowledge, their base formed at school is the starting point from which the next stage in the student's life begins.

Unfortunately, it should be noted that in recent years there has been a decline in the level of school education of graduates of secondary educational institutions. The introduction of new curricula does not correct, and sometimes exacerbates this situation. There are various subjective and objective reasons leading to this. Among the main ones are a sharp increase in the amount of information in various sections, caused by the development of science and an increase in the availability of information, the inertia and conservatism of school programs and educational technologies. One of the reasons is that programs and textbooks for different courses are compiled by different people who specialize in certain areas of knowledge. These people do not see the general picture of emerging knowledge, they try to fill their subject with as deep new data and definitions as possible, to increase the number of hours allotted for studying the subject at school. Sometimes such an increase in material leads to the fact that the school curriculum in some sections of the subject practically does not differ from the programs of higher educational institutions. According to the authors of these programs, this should lead to interest in their subject, "improvement" of the quality of knowledge on the subject. In fact, this only leads to the fact that students have to remember a lot more information (sometimes unrelated), which leads

to overload and confusion of students. No group of specialists will be able to fully take into account and calculate all the issues related to education, since these problems are multidirectional and multilevel. The traditional educational system cannot provide graduates with a timely and proper level of knowledge. To maintain a high level of demand in the labor market, students must rapidly update the necessary knowledge, the volume of which doubles on average every year and a half, which requires constant retraining. The problem can be solved by creating intelligent computer education systems based on very large knowledge bases. Such systems should make it possible to correct mistakes made in approaches to the development of knowledge, to take into account changes in the requirements for graduates' competencies that appear with the development of scientific and technical knowledge and the material and technical base of society more quickly and efficiently. Digital technologies will create an education system that will be more efficient and balanced.

What should an intelligent system be able to do and what knowledge base should it possess? In the intellectual system, a knowledge base should be formed, covering all the knowledge that a graduate should have at the end of school. The knowledge base should be multi-level. Otherwise, there will be no deep convergence between the preparation of students and the knowledge that they should have at the end of school. This part of the general knowledge base should cover all subjects of the school curriculum, but only to the extent sufficient to understand and assimilate information on each subject. Also, the knowledge base should take into account the problem of the amount of information, taking into account the complexity of the material that can be mastered in a particular period of study. Based on this knowledge, the intellectual system must form a training program, distribute during which period of study specific sections of various subjects are studied and at what level knowledge is formed during this period. At the same time, the intellectual system should take into account what knowledge the student has when he starts studying a new topic. By this time, the student should know all the necessary prerequisites, have knowledge in this and other subjects necessary to study the topic. As a result, a balanced distribution of all studied material from various subjects over time should be formed. Since the volume of the studied material, taking into account the complexity and the training time, have a finite value, the intellectual system must limit the amount of materials given for training in each period of time, and cut off materials that only increase the amount of memorized data, but do not carry any additional information necessary to understand and master the basic laws and phenomena. As a result, a model of the subject area should be created for each discipline, taking into account interdisciplinary links. In this regard, it is very important to provide technological means of "transition" of boundaries between educational materials of different academic disciplines. The domain model plays a major role, since it is used to solve the problems of structuring and systematizing educational material, implementing navigation and search algorithms for educational material and implementing adaptive learning management, etc. In ideal case, the student should be able to work with educational material in solving a number of problems not on the scale of a single academic discipline, but on the scale of all disciplines related to the issue under study. It is necessary to mention the logical organization of educational material within the framework of the specialty, which allows you to identify the connections of academic disciplines, certain topics of these academic disciplines, their constituent fragments (theorems, definitions of concepts, etc.) with other academic disciplines, topics, fragments of educational material, subsequent and previous. It becomes possible to determine a more rational sequence for studying educational material. The knowledge management system located in the knowledge base should also ensure the collection and systematic organization, analysis of data and knowledge from various sources, replenishment of the knowledge base from within the system itself.

An intelligent subsystem with an open, self-supplementing database should also be created, which will grow over time as topics in various subjects are covered. An educational approach based on the gradual filling of the student with knowledge and skills through their gradual presentation within a set of disciplines remains relevant. At each stage of training, the student should have access to the level of knowledge in the database that corresponds to the material he has studied. learning based on these assessments, i.e. an intellectual system should itself consist of a number of subsystems containing knowledge bases semantically correlated with each other.

The individual activity of students is an important component of education, which forms the skills of the student, contributes to the most effective assimilation of knowledge, determines his inclinations and contributes to their development. Individual activity is present in various ways of studying information: training in a mandatory program, additional optional individual training. Additional types of education may use information that is not included in the mandatory school curriculum. Such broader information should be available to students, but it should be in the general knowledge base and used for additional, optional or independent education. The development of this information should take place outside the main school education, both in terms of time and information and program components, and contribute to the development of individual abilities of students.

In any type of learning with the participation of intelligent learning systems, the student needs an assistant - "personal assistant" = "personal manager", who will help establish communication with the intelligent system and make its use more efficient. Personal assistant" of each user participant is included in the system in order to ensure both the security of the system and the comfort of the user's work already at the stage of the first interaction of the user with the intelligent interface. An adaptive approach to designing a user interface in educational systems is one of the promising directions for the development of this class of systems. This approach provides for the creation of a flexible structure of the dialogue between the system and the user in accordance with a number of individual characteristics of the user: readiness to work with the system, characteristics of interaction with the system, interface preferences, individual psychological characteristics.

Since the development of the educational system is supposed to be organized on the basis of a common OSTIS system, it is natural to use common approaches when building separate subsystems. The developed general models of the interface of the OSTIS metasystem must be adapted for the educational OSTIS system. This will significantly reduce the material and time costs for building the system interface.

Along with the task of creating a personal user interface, a personal manager has many other tasks. It forms a spectrum of information about the learner. Determines his inclinations and abilities in a particular field of knowledge. When considering individual topics studied, a personal manager helps to form a variant of navigation through semantic links, when a student or a system forms a certain path, reveals a feature, moves to the next feature, and so on through the educational material; proposes tasks on laws from the studied material, at the next stage - tasks in which, along with this, material from previously covered topics, including from other subjects, is used, then tasks of an even more complex level are proposed. Also, a personal manager must form a system for evaluating results at each stage of training. This is a constant unobtrusive diagnostics of the state of the student and the adjustment of his learning model based on the analysis of the control results. It is formed, on the one hand, on the basis of information about how much time the student spent studying the topic, the tasks of what complexity he was able to solve, etc. On the other hand, a personal manager must form a "reasonable" question-answer system based on the specified material (i.e., a system capable of finding answers to a sufficiently large number of questions regarding the meaning and semantics of the relevant material).

IV. Ways to the educational activities automation

The adjustment of the learning process should take place on the basis of these assessments, forming a set of necessary information for the next level, i.e. an intellectual educational system should itself consist of a number of subsystems containing knowledge bases semantically correlated with each other, specialized databases and knowledge, electronic textbooks, including those prepared using hypermedia and multimedia, as well as network sources based on the Internet. Thus, the requirements for the efficiency and practice orientation of training systems are constantly increasing, which leads to the inevitable realization of the relevance of the problem of developing such computer training systems, which should provide:

- processing of large volumes of complex structured information of various types;
- flexibility and easy modifiability of the system;
- integration of various models and mechanisms for solving problems;
- support for various models of learning and user interaction management;
- integration of various software systems within one system and management of their operation and interaction;
- widespread use of multimedia;
- operation in real time.

It is also possible to formulate the basic requirements for intelligent learning systems at different levels of education, as follows:

- Versatility. Availability of means of representation and processing of educational and educational-methodical knowledge, focused on any subject area;
- Adaptability. Availability of means of forming a model of the student and means of adapting the educational process to the student;
- Flexibility. The availability of tools that allow the implementation of various learning models, as well as supporting various forms of learning;
- Extensibility. The ability to modify existing system properties and add new properties without violating the conceptual integrity of the system;
- Distribution. Availability of means of organizing remote access to the system. Ability to work with the system from different locations (locally and remotely) at any time.

To implement such properties of educational intelligent semantic systems and meet the requirements for them, it is necessary to develop and build systems such as:

- The semantic model of the learner, which provides the personification of learning (adaptation) to the learner (give examples of specific ontologies);

- Semantic model of various pedagogical methods;
- Semantic model of general management of the process of individual learning.

An example of building such intelligent learning systems can be an intelligent learning system based on semantic electronic textbooks [11]. An electronic textbook, as a rule, is used for independent study of an academic discipline. As far as the knowledge presented in the electronic textbook is well structured, their completeness and consistency, clarity and accessibility, the possibility of quick associative search are ensured, the effectiveness of the learning process increases. Semantic electronic textbook - a set of software tools built using methods and tools of artificial intelligence, in particular, OSTIS technology, in which the knowledge base of educational and educational material is presented in the form of a hypertext semantic network and the possibility of associative access to any fragment of this educational material is provided. Such a textbook is based on a knowledge base, since that the electronic semantic textbook turns into a fairly "reasonable" question-answer system for the specified material. This means that the SEU becomes a system that "understands" the meaning of the educational and teaching materials contained in it.

An intellectual learning system should be able to track the consistency and integrity of the picture of the world presented in it and presented to the student, teach through its own ability to solve problems, contain a system of assessments and decision-making on a learning strategy based on these assessments, i.e. should itself consist of a number of subsystems containing knowledge bases semantically correlated with each other. The knowledge base of the intelligent educational system as a whole should also be semantically correlated across various disciplines (directions) of education. This can be represented by a system of OSTIS communities that provide educational activities in the field of AI within the overall OSTIS ecosystem as an association of structures, objects and their interaction with each other and with the external environment. The high connectivity of knowledge bases of the OSTIS ecosystem subsystems, a single technology for their organization and effective interaction, a variety of technologies used within the ecosystem, independence from the interface language, combined with the ability to include new subsystems built on the same principles, makes this approach a key success factor in analysis and synthesis of a comprehensive solution for the organization of educational activities at all levels of education in our society.

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Автоматизация образовательной деятельности в рамках экосистемы OSTIS

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Представлен анализ необходимости комплексной реструктуризации системы образования с учетом требований цифровой экономики. Определены пути решения некоторых проблем реализации образовательного процесса на уровне общего школьного образования. Предложен семантический подход к построению комплекса интеллектуальных обучающих подсистем, включающих обучающую, вспомогательную обучающую и аналитическую, сопровождающую учебный процесс, в рамках Экосистемы OSTIS.

Received 13.03.2023