Designing an Ontology of the Educational Process in a Specialized Secondary Education Institution

Lizaveta Bushchik
Belarusian State University of Informatics and Radioelectronics
Minsk, Belarus
e.bushchik@bsuir.by

***Abstract*—The paper presents the author's results on the use of information technology to automate business processes in the Republic of Belarus, in particular, it shows the development of partial automation of business processes for different levels of the education system. On the example of a specialized secondary education institution, the author substantiates the relevance and necessity of implementing digital twin technology in the educational sphere of the Republic of Belarus. The stages of building a digital twin of the educational process developed by the author are highlighted. On the basis of the process approach of business process modeling the upper ontology of the college is formed. Examples of graph model of ontology with the help of OSTIS technology are given.**

***Keywords*—secondary specialized education institution, digital twin, interoperability, automation, expert system of educational process management, ontology, knowledge base, OSTIS technology**

I. Introduction

In today's digital society, information is becoming a strategic resource, and information technology is one of the tools for improving the efficiency of economic and social systems management, including the education system. Currently, the most actively developing and implementing such technological trends as: artificial intelligence, machine learning, Internet of Things, virtual and augmented reality, robotic process automation, blockchain, autonomous vehicles, digital twins, cybersecurity, 3D printing.

The introduction of information technologies in the spheres of public administration is a task of strategic importance. That is why the State Program "Digital Development of the State for 2021-2025" has been developed and approved, the tasks of which are largely determined by the main provisions of the National Strategy for Sustainable Development of the Republic of Belarus for the period until 2035.

The purpose of the State Program is to ensure the introduction of information and communication and advanced production technologies in the sectors of the national economy and spheres of society. In order to realize this goal, it is necessary to implement complex automation of information systems in various spheres – medicine, education, public administration, production, transport, agriculture, etc. The State Program is aimed at ensuring the implementation of information and communication technologies and advanced production technologies in various sectors of the national economy and spheres of society.

Figure 1 shows the statistics of the BEROC research center on the surveyed private and state-owned enterprises of the Republic of Belarus, which reflects for 2019 the use of information technology to automate business processes in the following areas:

- accounting – 93.4%;
- personnel accounting and sales – 47.9%;
- warehousing – 46.5%;
- document management – 41.5% and others [1].

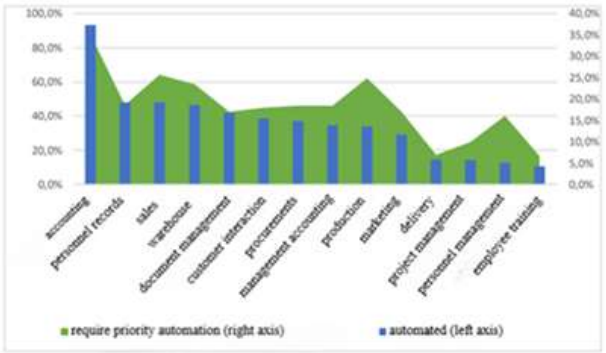

Figure 1. Automated and business processes requiring priority automation.

Thus, as of today, partial automation of business processes has been implemented, i. e. there is no unified information system that ensures the adoption of sound management decisions based on quality and reliable information obtained with the help of modern information technologies.

II. Digital twins

A. Digital twins in the Republic of Belarus

To realize complex automation of business processes, a so-called digital twin (twin) is required. By digital twin we mean a dynamic digital model of a real system, which can use data from sensors to assess its state, react to changes, improve its operation and perform additional functions. A digital twin can be a digital model that includes a combination of metadata, i. e. structured data such as classification, composition, material specification, structure, guidelines and other conditions and states (location, temperature), event data and analytics (algorithms, rules). Their practical application is associated with preventive maintenance and prediction of equipment failures, process planning, and improving the efficiency of systems management in general [2].

The National Statistical Committee of the Republic of Belarus conducted a study of the use of different digital technologies in their activities by private and public organizations for the year 2023, which showed the percentage as follows (Figure 2):

- "internet of things" – 18.5%;
- radio frequency identification technologies – 13.7%;
- "big data" – 12.3%;
- artificial intelligence – 3.6%;
- "digital twin" – 0.6% [3].

Thus, the application of digital twin technology is at the early stages and requires further development and integration into various spheres of economy and management, including the education system.

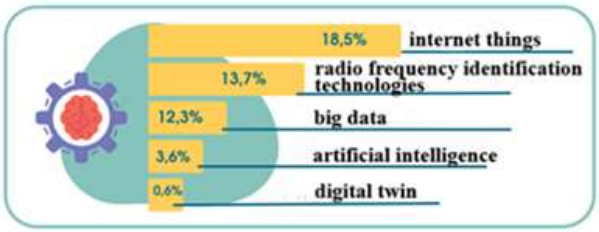

Figure 2. Statistics on the use of digital technologies.

The low utilization of digital twins may be due to a number of factors, such as lack of awareness of the benefits of this technology, limited financial resources for the implementation of complex systems, and a shortage of qualified specialists capable of working with such solutions.

Main areas in the Republic of Belarus, where digital twin technologies are developed and/or applied:

1) *Oil and gas production and refining*: the engineering data management system developed by the institute "Belorusneft' – Neftekhimproekt" was implemented in the republican unitary enterprise "Belorusneft' – Brestoblnefteprodukt".
2) *Industry:*
   a) Pilot project "Intellectual system of design and technological design and production preparation of products using digital technologies", developed by the central research and design and technological institute of organization and management techniques, two enterprises were chosen as platforms for the project – open joint-stock company "Minsk Mechanical Plant" named after S. I. Vavilov and open joint-stock company "Vityaz'".
   b) Robotic line of Belvest shoe production, developed by LACIT-Laboratory of Digital Technologies Limited Liability Company.
   c) Information system for automation of business processes based on the innovative software product "1C:ERP Enterprise Management 2.4" developed by YUKOLA-INFO-Brest, a company with additional responsibility.
   d) Digital twin of a dump truck and digital twin of a quarry - a joint development of SAP CIS and BELAZ.
3) *Energy:*
   a) Pilot projects on the creation of digital simulators, which allow operational personnel to practice skills of working on power equipment in real time while performing tasks, are developed within the framework of cooperation between organizations of the Ministry of Energy of Belarus and Rosatom State Corporation.
   b) "Digital twin" of operation of turbine units PT-60-130 of stations №1,2,3 of Bobruisk thermal power plant №2, developed by the republican unitary enterprise "Belnipienergoprom".
4) *IT sphere:* the Belarusian IT company "International Business Alliance" has developed the system "Chancellor RPA", designed for development, support and modification of program robots that simplify the support of business processes.
5) *Construction:* open Joint-Stock Company "Clay Gravel Plant Novolukoml" developed and placed in free access on the official website of the enterprise VIM-models of claydite concrete blocks "ThermoComfort".
6) *Education:* virtual and Augmented Reality Laboratory, developers: InnowiseGroup (Limited Liability Company "Factory of Innovations and Solutions") for P.M. Masherov Vitebsk State University).
7) *Medicine:*
   a) The Republican Scientific and Practical Center "Cardiology" has developed a technique

for creating a virtual heart model for 3D printing.

b) An automated information system “Electronic Prescription” has been developed.

8) *Sport:* developed by the Ministry of Sports “Digital Movement Laboratory”. This technology is used to check physical development during certain exercises. Such technology is used by highly professional athletes in the training process to adjust training.

9) *Urbanistics:* implementation of the regional state standard digital platform ”Smart City (Region)" in the city of Minsk, regional centers, cities and districts with a population of 80 thousand people and more, providing on their basis services in various spheres of life and management.

In the Republic of Belarus, digital twins have been implemented in manufacturing – for example, in machine and equipment manufacturing enterprises, where models are used to optimize processes and improve efficiency, and in healthcare – for example, in the development of virtual models for planning surgical operations and monitoring patients' condition. In education, there are practically no developments with the use of this technology, so it is becoming increasingly important to implement digital twins, which can help to create individualized educational programs, analyze students' academic progress, optimize the learning process and other opportunities in accordance with the needs of the educational institution.

B. Digital twins in the field of education in the Republic of Belarus

Digitalization of educational processes is one of the most effective ways to improve the quality of learning and management of the learning process in educational institutions. This is especially relevant in the context of rapid technological development and the need to adapt educational systems to modern requirements. In this regard, educational institutions are beginning to implement various information technologies and automated systems to optimize their business processes.

Existing information technologies in the educational sphere are limited to performing a set of specific functions, leaving a significant part of management decisions to human judgment. This results in teachers and administrators having to rely on their experience and intuition rather than on the data provided by systems in situations that require a quick response (e. g., low group performance or schedule changes). Within the framework of the direction of education there are the following developments on partial automation of business processes:

At the level of higher education within the framework of realization of the concept of digital university 4.0 corporate information systems are being developed, which include subsystems:

- for management processes: subsystem “Reporting and analytics”, subsystem “Administration of university-wide classifiers”, subsystem “Divisions”;
- for operational processes: subsystem “Students”, subsystem “Educational and methodological support of the educational process”, subsystem “Schedule”, subsystem “Journal of current academic progress”, subsystem “Curator's Journal”, subsystem “Dean's Office”, subsystem “Department”, subsystem “Gifted Bank”, subsystem “Student's Personal Cabinet”, subsystem ‘Rating’, subsystem “Employee's Personal Cabinet”, subsystem “Electronic Applicant”, subsystem of e-learning (Moodle);
- for supporting processes: “Dormitory” subsystem, ‘Passportist’ subsystem, “Military registration desk” subsystem, “Student Personnel Department” subsystem, “Production and accounting of student credit books” subsystem, "1C: ERP Enterprise Management (1C ERP)“ - ”Salary“, ”Scholarship“, ”Payment for Hostel“, ”Payment for Education“, ”Personnel Department“, ”Planning and Finance Department“, ”Extra-budgetary bonuses“, ”Children's allowances“, ”Assignment of orphans' allowances“, ‘Deponents’, ”Accounting of budgetary and extra-budgetary financing of money and expenses (Banks)", “Accounting of Material Assets”, automation of information exchange through the “Client-Bank” system, automation of information exchange with the Federal Social Security Fund“, the EUMKD subsystem, the ”Electronic Library“ subsystem, the ”Telephone Directory“ subsystem, and the ”User Administration" subsystem.

At the level of secondary specialized education on the basis of “1C:Enterprise 8” the implementation of the configuration “1C: e-College PROF” will be introduced, this information system was developed within the framework of the pilot project of EE RIPO. Business processes of both activity planning and execution control are automated: preparation of working curricula on the basis of state standards, formation, distribution and accounting of teaching load, scheduling and accounting of daily substitutions, planning and control of execution of activities, accounting of academic performance and attendance, planning and implementation of industrial practice and many others.

The development of automated information systems in each educational institution is individualized using different programming technologies. Consequently, the transition to digital transformation and the creation of a unified republican information and educational environment, laid down in the Concept of Digital Transformation of Processes in the Education System of the Republic of Belarus for 2019-2025 [4], is impossible due to the

lack of open systems and interoperability between these systems [5].

III. Stages in the development of a digital twin

To solve the problem of ensuring openness and seamless information integration of subsystems within the information system of an educational institution and between systems in general, it is proposed to use a digital twin of the functioning environment of an educational institution. The proposed digital twin should consist of expert systems for each business process of a specialized secondary education institution. The structure of the expert system is based on: knowledge base, solver, help and explanation subsystem. The generalized structure of the expert system is presented in Figure 3.

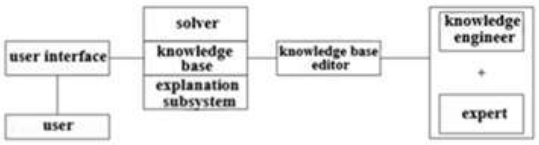

Figure 3. Structure of the expert system.

The blocks shown in Figure 1 are present in any expert system. In general, the process of functioning of an expert system can be presented as follows: a user who wants to obtain the necessary information sends a request to the expert system through the user interface. The solver, based on the knowledge base, generates and issues a suitable recommendation to the user, explaining the course of its reasoning with the help of the explanation subsystem [6].

Knowledge base construction involves three steps:

- description of the subject domain;
- selection of a knowledge representation model;
- knowledge acquisition.

The development of the knowledge base consists in the allocation of the subject area, on the solution of which the expert system is oriented. In this case it is necessary to:

- determine the nature of the tasks to be solved;
- identify the objects of the subject area;
- establish links between the objects;
- select a model of knowledge representation;
- identify the specific features of the subject area.

A. Development of a knowledge base of a specialized secondary education institution

The main factor of ensuring compatibility of different types of knowledge, different models of problem solving and different computer systems in general is unification of information representation in the memory of computer systems. An objective guideline for unification of information representation is formalization of the meaning of the represented information.

OSTIS technology was chosen for the development of knowledge bases of the institution of secondary special education, which is based on a clear separation from the process of designing a formal description of the semantic model of the developed knowledge base to the process of implementation (interpretation) of this model on one or another platform. This fact allows to provide cross-platform development of intellectual systems. The knowledge base built using OSTIS technology is based on the hierarchy of subject areas and their corresponding ontologies, which allows, on the one hand, to localize the area of solving certain problems, and on the other hand, to describe the relationships between different concepts and ensure the inheritance of their properties.

In the framework of the subject area under consideration, covering the business processes of a specialized secondary education institution (college), a knowledge base was formed using an ontological approach based on the representation of information in the form of semantic networks (knowledge graphs).

To illustrate such a model, let us consider the top ontology of college activity in Figure 4. In this fragment, types of educational institutions are identified according to the levels of the education system, such as: higher education institution, specialized secondary education institution, vocational education. The real representative of the secondary specialized education institution is the college. The following structural units are defined for the college: Board, educational and methodological association, library, competence center, management, personnel service, department.

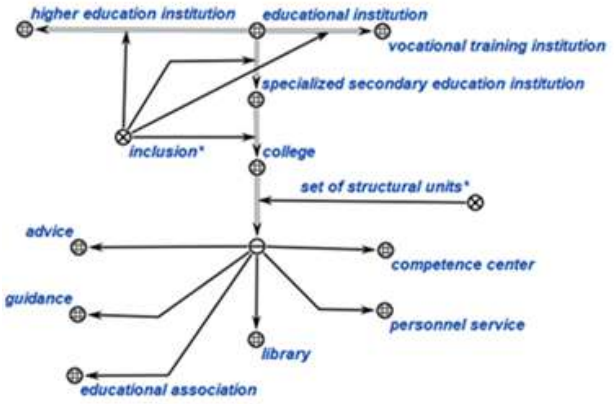

Figure 4. The upper level of formalization of the college.

The example of the branch of BSUIR Minsk Radio Engineering College shows that the college consists of departments, where there is a head of department (Figure 5). Here the real example of a department is the department of computer technologies. Each department is a representative of the general class of the department.

Figure 6 demonstrates the formalization of the department into cyclic commissions on the example of the

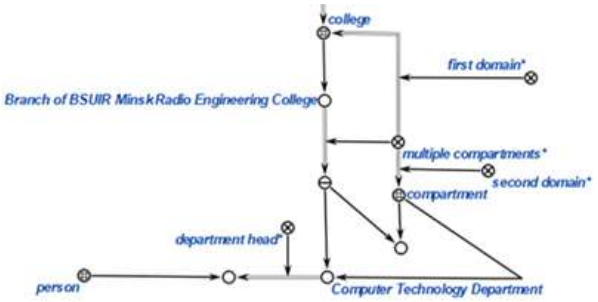

Figure 5. Formalization of the organizational structure of the college.

cyclic commission of information technology software. The cyclic commission is headed by the chairman. The cyclic commission consists of teachers with the following possible categories: highest, first, second, no category.

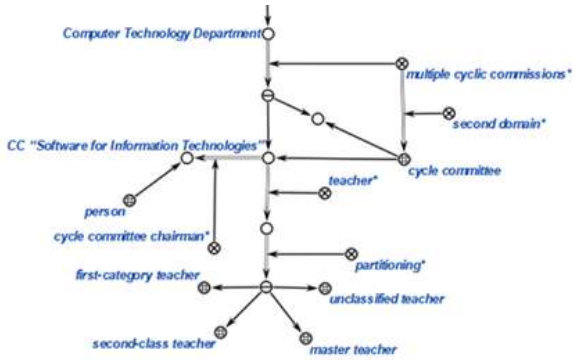

Figure 6. Formalization of college departments.

Figure 7 shows that the cycle commission, as the most important element of the college functioning, implements the educational process according to the regulations of educational and methodical documentation in accordance with the direction of a particular specialty. The educational standard and the curriculum of the specialty are chosen as the basis of educational and methodical documentation.

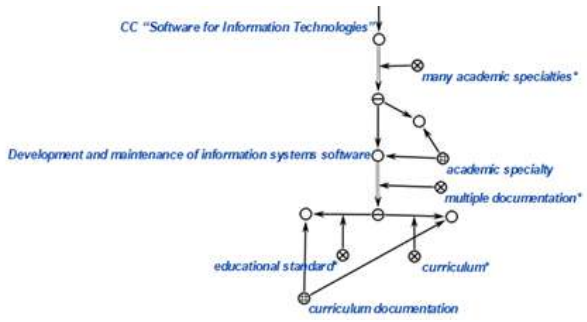

Figure 7. Formalization of the cycle commission of the college.

Figure 8 demonstrates that the curriculum of the specialty consists of academic disciplines, for which the teaching hours of the following types are defined: lectures, practical and laboratory classes, seminar.

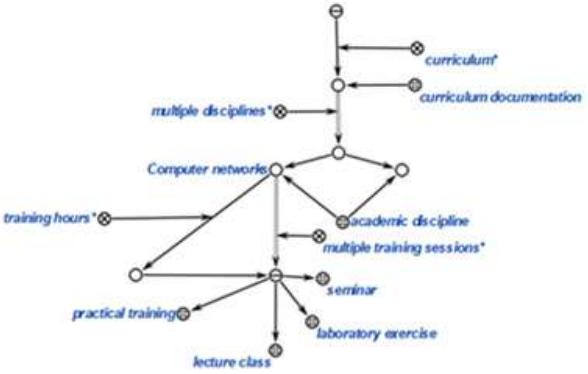

Figure 8. Formalization of the curriculum of the specialty.

Within the framework of formalization are highlighted:

- Terms: “Educational institution”, “Institution of secondary special education”, “College”, “Board”, “Management”, “Competence center”, “Department”, “Educational and methodological association”, “Personnel service”, “Head of department, ”Chairman of cycle commission“, ”Teacher“, ”Cycle commission“, ‘Category’, ”Curriculum documentation“, ”Teaching hours".
- Attributes: “No category”, “Second category”, “First category”, “Higher category”, “Teaching specialty”, “Educational standard”, “Sample curriculum”, “Teaching discipline”, “Practical lesson”, “Lecture lesson”, “Laboratory lesson”, “Seminar”.
- Relationships: “The teacher has the second category”, “The teacher has the first category”, “The teacher has the highest category”, “The cycle commission includes support of educational specialties”, “The educational specialty is based on the educational standard and exemplary curriculum”, “The exemplary curriculum contains a variety of academic disciplines”, “The academic discipline involves the passage of training hours of different formats: lecture, laboratory class, practical class, seminar”.

The presented list of terms, attributes and relations is far incomplete and can be extended and supplemented when designing an automated system.

This article presents a fragment of the ontology of activities of a specialized secondary education institution, it can also be extended depending on the tasks that need to be automated to make managerial decisions.

The developed ontology allows solving the following tasks:

- describe objects and processes of the educational process;
- describe relations between objects and processes;

- transform information from existing standards into a knowledge base and back, which together is the basis for the design and construction of an automated management system of an educational institution.

IV. Conclusion

The article presents an original model of business process ontology in the form of sets of terms, attributes and relations, and describes the composition of these sets. The model of the upper ontology of the activity of a specialized secondary education institution is developed in the form of a graph formalizing the activity of a specialized secondary education institution and a graph formalizing the activity of a cycle commission, which can serve as a basis for the development of expert systems for managing the educational process. Since the formalization of activity is represented with the help of OSTIS-technology, the developed upper ontology will allow to unify data, improve interaction between the participants of the educational process and increase the quality of decisions. It can be predicted that in the future the introduction of such systems can significantly improve the efficiency of learning and adaptation of educational programs to the requirements of modern society.

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ПРОЕКТИРОВАНИЕ ОНТОЛОГИИ ОБРАЗОВАТЕЛЬНОГО ПРОЦЕССА В УЧРЕЖДЕНИИ СРЕДНЕГО СПЕЦИАЛЬНОГО ОБРАЗОВАНИЯ

Бущик Е.А.

В работе представлены результаты автора по использованию информационных технологий для автоматизации бизнес-процессов в Республики Беларусь, в частности, показаны разработки по частичной автоматизации бизнес-процессов для разных уровней системы образования. На примере учреждения среднего специального образования обоснована актуальность и необходимость внедрения технологии цифрового двойника в образовательную сферу Республики Беларусь. Выделены разработанные автором этапы построения цифрового двойника образовательного процесса. На основе процессного подхода моделирования бизнес-процессов сформирована верхняя онтология колледжа. Приведены примеры графовой модели онтологии с помощью технологии OSTIS.

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