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RESEARCH ARTICLE

Developing the data management component of an academic discipline program for an educational management information system

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Abstract
Objectives. The need to apply methods and models to support the educational process at universities including the formation and management of academic discipline programs (ADPs) is determined by the growing need for the active implementation of various automation tools including integrated information systems, which arise in response to a number of regulatory and legal factors. Such social factors result in the significant increase in the volume and categories of information circulating within business processes of an educational organization, as well as the expansion of the requirements for ensuring the protection, storage, and transmission of information. In recent years, the Government of the Russian Federation has approved the national "Digital Economy" and "Education" projects (including the Federal Project "Digital Educational Environment") emphasizing the growing role of informatization and digitalization processes in education. In this connection, an obvious discrepancy arises between the theoretical characteristics of information flows existing in educational organizations and the methods of its collection, processing, storage, analysis, and application used in practice. One of the most important conceptual components of the educational process in higher education institutions is the ADP, which organizes the relationship between various components of the educational process: curriculum, competencies, training areas, learning technologies, and methods for conducting the control check of students' knowledge. The labor-intensive and variable nature of ADP development and implementation requires the introduction of information technologies. Thus, the aim of the present work is to analyze the volume and structure of institutional educational programs in order to identify the necessary software requirements.
Methods. The classification of learning management systems according to various criteria, key requirements for academic disciplines, and ADP structure is considered.
Results. An analysis of links between the ADP and key entities of the educational process is presented. The functionality of the self-developed ADP module for implementing at RTU MIREA is aimed at providing interconnection, transparency, and availability of links between academic discipline parameters and its sections.
Conclusions. Introducing the ADP module allows reducing the time spent on developing the program by providing universal templates of academic disciplines, along with the possibility of autofilling the academic discipline parameters and tracking the current status of ADPs, as well as increasing the level of awareness of participants in the educational process.

Keywords: educational process, data management, digitalization, educational environment, information systems to support the educational process, educational programs and standards, academic discipline program

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НАУЧНАЯ СТАТЬЯ

Разработка компонента управления данными программы учебной дисциплины для информационной системы управления образовательной средой

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Резюме

Цели. Потребность в применении методов и моделей поддержки учебного процесса в образовательных организациях высшего образования, в т.ч. формирования и управления программами учебных дисциплин (ПУД), определяется растущей необходимостью активного внедрения средств автоматизации, включая комплексные информационные системы. Это вызвано наличием нормативно-правовых и социальных факторов, приводящих, с одной стороны, к существенному увеличению объемов и категорий информации, циркулирующей в рамках бизнес-процессов образовательной организации, а с другой стороны, к расширению требований, предъявляемых к обеспечению защиты информации, ее хранению и передаче. В 2018–2019 гг. Правительством Российской Федерации утверждены национальные проекты «Цифровая экономика» и «Образование» (в т.ч. федеральный проект «Цифровая образовательная среда»), подчеркивающие растущую роль процессов информатизации и цифровизации в образовании. Следует отметить очевидное несоответствие между характеристиками существующих в образовательных организациях информационных потоков и способами их сбора, обработки, хранения, анализа и применения на практике. Одной из важнейших составляющих образовательного процесса в организациях высшего образования является ПУД, позволяющая организовать взаимосвязи между различными составляющими учебного процесса: учебным планом, компетенциями, направлениями подготовки, технологиями обучения и способами осуществления контрольной проверки знаний обучающихся. Разработка и реализация ПУД является трудоемким и вариативным процессом, который требует внедрения информационных технологий. Цель работы – анализ объема и структуры образовательных программ учреждения для выявления требований к необходимому программному обеспечению.

Методы. Рассмотрена классификация систем управления обучением по различным признакам, ключевые требования к учебным дисциплинам и структура ПУД.

Результаты. Проведен анализ связей ПУД и ключевых сущностей учебного процесса. Рассмотрены функциональные возможности модуля собственной разработки ПУД для внедрения в РТУ МИРЭА, направленные на обеспечение взаимосвязи, прозрачности и доступности связей между параметрами учебной дисциплины и ее разделами.

Выводы. Введение модуля ПУД позволит уменьшить временны́е затраты на разработку программы путем предоставления универсальных шаблонов учебных дисциплин, возможности автозаполнения их параметров, отслеживания текущего статуса ПУД, и повысит уровень информированности участников образовательного процесса.

Ключевые слова: образовательный процесс, управление данными, образовательная среда, информационные системы поддержки учебного процесса, образовательные программы и стандарты, программы учебных дисциплин

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INTRODUCTION

Information technologies are widely used in all spheres of human activities including education. The introduction of information systems (IS) into the educational process contributes to its rational organization and the creation of the unified information space for the educational institution and direct participants in the learning process.

The information educational environment is the systematically organized set of information technologies as well as hardware, software, and methodological support along with electronic educational resources for organizing the educational process wherein a person plays the role of the subject [1, 2]. The digitalization of the following areas is required for the functioning of the information educational environment in a higher educational institution (HEI):

- information and methodological activities,
- planning the learning process and resource provision,
- placement and storage of training materials,
- monitoring,
- distance education [3].

The need to digitize these areas of activities has given rise to the special type of IS being the Learning Management System (LMS). This term implies the use of IS to provide support to the e-learning process in terms management, monitoring, and documenting, as well as providing the learning content and control [4]. This IS support may be distinguished into methodological, administrative, and technological strands. The ISs themselves comprise software or platforms aimed at providing teachers and students with the necessary tools to organize and conduct the learning process including distributing the reference and lecture materials, as well as generating reports.

The functionality of modern LMSs may be complemented by software products such as the Training Management System (TMS) for implementing the learning process under the teacher control and the Learning Record Store (LRS) for tracking and recording user actions. LMSs find application for solving various tasks ranging from IS providing means for online courses up to systems of the corporation level which functionality is regulated by GOST R 52653-2006[1] and GOST R 52655-2006[2] standards.

DOMESTIC AND INTERNATIONAL EXPERIENCE IN IMPLEMENTING IS INTO EDUCATIONAL ACTIVITIES

By the early 1980s, personal computers had already become much more accessible to users, resulting in the increasing use of software in the educational process. The first IS supporting the educational process and its components appeared in 1980. Among the most popular IS, the ToolBook and TenCORE authoring systems were used to create interactive content for learning. The computer managed instruction (CMI) systems FirstClass and TrainingPartner[3], which were among the first IS for automating educational process components, use formal language and specifications to create training courses and integrate them into the distance learning system. The first tools for working with email, forms, and interactive whiteboards were also introduced in FirstClass and TrainingPartner.

A complex of automated management systems for higher education institutions already being developed in Russia at that time would go on to become the first IS to support the educational process. This software developed by the Research Institute of Higher Education Problems of the USSR covered the entire learning process ranging from admission to the university up to the completion of education [5]. According to the centralized implementation process, the system went on to be integrated into more than 50 different educational institutions deemed as having the greatest technical and intellectual potential.

Along with the development and growth of the number of IS supporting the educational process components,

[1] GOST R 52653-2006. *Information and communication technologies in education. Terms and definitions*. Moscow: Standartinform; 2007 (in Russ.).

[2] GOST R 52655-2006. *Information and communication technologies in education. The integrated automated control system of the high professional educational system. General requirements*. Moscow: Standartinform; 2007 (in Russ.).

[3] LMS-Timeline. https://www.rockymountainalchemy.com/cudenver/INTE6750/Emergence/LMS-Timeline.html. Accessed April 15, 2022.

various standards governing the processes of their development and implementation become the subject of active development. An example of this type of standard is the Sharable Content Object Reference Model (SCORM)[4], which focuses on the requirements for the formation of educational literature for distance learning systems. Here, the key idea is to compile electronic resources from shared content objects [6]. SCORM aims at implementing the interoperability of all elements of the education programs with all LMSs and virtual learning environments [7]. In accordance with this standard, educational materials are presented in the form of blocks, allowing them to be included in different courses and disciplines and providing the possibility of their independent use as part of a distance learning system. Since essentially consisting of a set of technical rules focused on providing the reader with knowledge about course design and lesson structure, as well as the description of the principles of interaction with the system, SCORM becomes relevant to programs within academic disciplines (ADPs). This standard puts forward the following three key requirements for the learning program components:

- the presence of manifest file containing the complete description of the course and all its components;
- course metadata represented by the image, video file, or HTML page should be associated with the specific metadata file;
- the presence of the program interaction language to implement communication between the learning organization system and the learning program.

Such educational support systems as Moodle[5], Sakai[6], ATutor[7], ILIAS[8], and others are implemented using this standard.

Today, the most preferable solutions for educational institutions are not off-the-shelf solutions but the systems providing flexible tools to support the learning process, which may be further improved in the future [8, 9].

IS ROLE OF ADP COMPONENT IN SUPPORTING THE EDUCATIONAL PROCESS

Although many LMSs offer similar functionality, individual systems may differ significantly in a number of key parameters, thus complicating the decision-making process for using a particular system in the educational institution. In order to identify different types of LMS, the following characteristics may be used as classifiers:

- license type;
- functionality;
- modularity;
- requirements imposed by the customer to the system;
- the system physical location features [8].

LMSs can also be classified into three types according to the type of license: free, partially paid, and paid. Free systems are characterized by their cost-free distribution. Partially paid systems are characterized by the presence of a minimal free functionality, which may be expanded upon payment of a fee.

Moodle is an example of one of currently most popular free LMSs. The system provides users with tools for both creating courses and monitoring the learning process. The key advantages are its simplicity and ease of use, while offering extensive opportunities for organizing the educational process and monitoring the knowledge of students, as well as its relative user-friendliness to third-party developers allowing their integration into the system [10].

The partially paid system may be exemplified by the eFront[9] system having a wide starting set of tools: glossary, testing, forum, chat, calendar, etc.

The paid systems include Dnevnik.ru[10], Moiuniver[11], YaKlass[12], SharePointLMS[13], BlackBoard[14], Desire2Learn (D2L)[15], and others.

Classifying IS by functionality, two types of LMS may be distinguished:

1) aimed at supporting the learning process upon the whole;
2) aimed at providing educational material and testing the knowledge of students only.

Examples of the first type are Moodle, Sakai, e-University[16], Education Elements[17], Ilias, Odijoo[18], ScormCloud[19], Dnevnik.ru, My University, YaKlass, and eFront.

The systems belonging to the second type may be exemplified by Claroline[20], Dokeos[21], LAMS[22], Learn eXact[23], and Coursera[24].

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[4] https://scorm.com/. Accessed April 17, 2022.
[5] https://moodle.org/. Accessed May 15, 2022.
[6] https://www.sakailms.org/. Accessed May 11, 2022.
[7] https://atutor.github.io/. Accessed May 13, 2022.
[8] https://www.ilias.de/. Accessed May 15, 2022.
[9] https://www.efrontlearning.com/. Accessed May 12, 2022.
[10] https://dnevnik.ru/. Accessed May 15, 2022 (in Russ.).
[11] https://moi-univer.ru/. Accessed May 21, 2022 (in Russ.).
[12] https://www.yaklass.ru/. Accessed May 15, 2022 (in Russ.).
[13] https://www.sharepointlms.com/. Accessed May 15, 2022.
[14] https://www.blackboard.com/. Accessed May 15, 2022.
[15] https://www.d2l.com/. Accessed May 15, 2022.
[16] https://dic.academic.ru/dic.nsf/ruwiki/1428198. Accessed May 26, 2022 (in Russ.).
[17] https://www.edelements.com/. Accessed May 26, 2022.
[18] https://rusticisoftware.com/blog/taking-scorm-to-odijoo/. Accessed May 15, 2022.
[19] https://rusticisoftware.com/products/scorm-cloud/?utm_source=google&utm_medium=natural_search. Accessed May 15, 2022.
[20] https://www.claroline.com/. Accessed May 15, 2022.
[21] https://www.dokeos.com/. Accessed May 15, 2022.
[22] https://www.lamsfoundation.org/. Accessed May 15, 2022.
[23] https://www.exactls.com/. Accessed May 15, 2022.
[24] https://www.coursera.org/. Accessed May 15, 2022.

Using the modularity criterion for classifying LMS, the autonomous and modular types of systems may be distinguished. The autonomous LMS is characterized by implementing all tools for the activities in one application. Modular LMSs are independent subsystems.

In terms of requirements, LMSs implemented as an off-the-shelf product or made on order in accordance with the needs of the customer organization may be distinguished.

In terms of physical location, the local, server, and cloud systems may be identified.

The local and server-based LMSs may be exemplified by Moodle, Tandem University[25], Ilias, ATutor, and WebTutor[26]. Cloud LMSs include Coursera, iSpring[27], Ed-modo[28], Odijoo, Scorm Cloud, TalentLMS[29], and Docebo[30].

In addition to the basic requirements for modern LMS such as reliability, convenience, and low cost for the educational process participants, the following additional requirements based on the classification features discussed above may be formulated:

- availability of flexible tools allowing the educational institution to implement the necessary functions within the educational process;
- support of SCORM or Tin Can API standard[31] to migrate content from one IS to another;
- adaptability.

The main trend in the LMS development is the transformation into the Next Generation Digital Learning Environment (NGDLE) being the ecosystem consisting of learning tools and components developed by general standards [11]. For proper functioning, NGDLE requires implementing the following functional features:

- the ability to analyze and evaluate the learning process;
- compatibility and the ability to customize the learning environment;
- simplicity and usability of the tools for both students and academic teaching staff (ATS);
- ensuring interaction and integration between different learning programs.
- The above functional features allow identifying four key dimensions for NGDLE:
- it should be possible to exchange learning content between all components of the system presented in a common format;
- the integration process should be easy and convenient to reduce the time costs and simplify the process of capacity building-up for the users;
- the learning environment should be the main source of data retrieval for the learning process;
- NGDLE should allow creating new interoperability standards in ways being compatible with its other standards to maintain overall consistency.

The NGDLE personalization covers two aspects:

- equipping and configuring the learning environment which is used then for building pathways to complete learning tasks and achieve learning goals;
- adaptive learning in which the automated system provides students with coaching and suggestions tailored to each student needs.

There has been significant recent momentum in adaptive learning, and this should be a feature of the NGDLE landscape. As with other NGDLE functional areas, integrating adaptive learning tools capable of providing data on student to support analytics would be crucial.

Within the context of NGDLE for analytics, two main components may be distinguished:

- learning analytics characterized as the measurement, collection, analysis, and reporting of student data in order to understand and optimize the learning process itself and the environment wherein it occurs;
- integrated planning and advising systems defined as the institutional capacity to make educational progress by creating a common space for all participants in the educational process. This space should contain the information and set of services necessary for a certain level of education.

It should be noted that most of the major LMS platforms have built-in functionality to perform learning process analytics based on data from IS and LMS. Based on this, such modules may be considered as first-generation attempts. Future analytics modules may be placed outside LMS, while their dashboards can be accessible for viewing in LMS or other applications using the Interoperability specification (the protocol describing interaction of learning platforms that is Learning Tools Interoperability, LTI). The results of the transition to NGDLE would be an increase in the amount of stored data; integration of appropriate tools aimed at improving the work quality; the ability to use analytical functions for evaluating the learning process.

SELECTING AN IS MODEL FOR ORGANIZING THE EDUCATIONAL PROCESS AT RTU MIREA

Educational programs offered at RTU MIREA were analyzed in the context of selecting the appropriate IS model (Fig. 1) [12]. The following key factors were identified:

[25] https://tandemservice.ru/products/tandem-university. Accessed May 15, 2022 (in Russ.).

[26] https://webtutor.ru/_wt/main_web. Accessed May 15, 2022 (in Russ.).

[27] https://www.ispring.ru/. Accessed May 15, 2022 (in Russ.).

[28] https://soware.ru/products/edmodo. Accessed May 15, 2022 (in Russ.).

[29] https://www.talentlms.com/. Accessed May 15, 2022.

[30] https://www.docebo.com/. Accessed May 15, 2022.

[31] Tin Can API is a specification of programs in distance learning, which allows training systems to communicate with each other by tracking and recording training classes of all types.

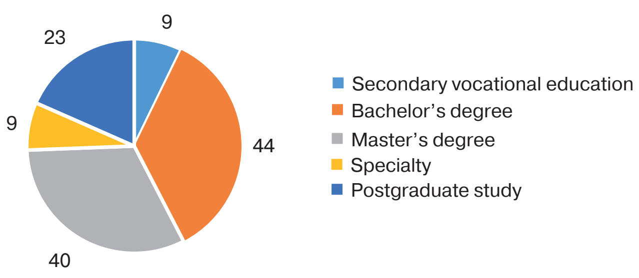

Fig. 1. Number of RTU MIREA educational programs

- territorial—conditioned by the location of classrooms and basic departments;
- quantitative—reflecting the number of students to include those who will only enter the university, i.e., making allowance for the dynamics of their enrollment (Fig. 2);
- implementation—degree of integration of current IS into the institution activities, as well as the level of their interdependence [13, 14].

As a result, it was decided to allocate the ADP management subsystem as a specialized LMS component.

The learning process at RTU MIREA is carried out in accordance with the basic educational programs reflecting its key components [14, 15]. As well as defining the learning process itself, the working ADP reflects the following key components:

- thematic focus of the discipline;
- competencies to be obtained by the student according to his or her achieved results;
- number of hours and order of lectures, practical, and laboratory classes, including independent work carried out by the student
- the classroom hardware and software;
- format and methods for testing and control of the student knowledge;
- recommended literature;
- questions for test or exam, etc. [14, 15].

The process of ADP development, formed in accordance with the needs of the labor market, is regulated by Federal Law No. 273-FZ of December 29 "On Education in the Russian Federation".[32] When creating an ADP, it is necessary first of all to be guided by its purpose. The educational process is aimed at ensuring that a student master a set of key skills and competencies provided by the training area or specialty. There should be a relationship between all types of obtained competencies by determining the place of the academic discipline in the learning process to provide the future specialist with a complete picture of his/her chosen specialty.

The ADP design and implementation process should be guided by three key principles: interconnectedness, transparency, and accessibility.

The first requirement is an attribute of any learning process reflecting the relationship between the various elements of the learning process including curriculum, competency map, educational standards, etc. The second requirement refers to the processes of agreeing and approving the learning program. The third requirement implies the program should be accessible to all participants in the learning process, i.e., including teaching staff and students.

Today, although LMSs are used at almost every university, the main disadvantage is the lack of a "boxed solution" that would reduce the load on the teaching staff by taking over most of the tasks related to creating a working ADP. In future, such a solution should offer the following:

[32] http://pravo.gov.ru/proxy/ips/?docbody=&firstDoc=1&lastDoc=1&nd=102162745. Accessed May 15, 2022 (in Russ.).

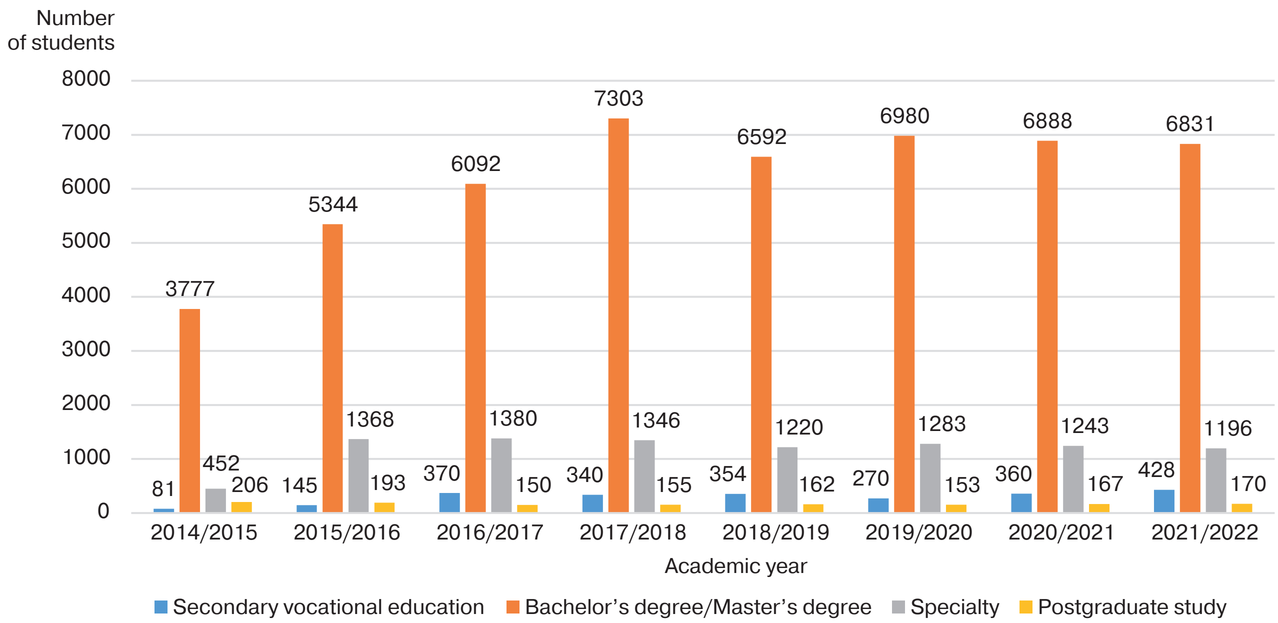

Fig. 2. Dynamics of the number of students enrolled in RTU MIREA

- compensate for the increased teaching staff workload in drafting documents supporting the educational process;
- reduce the document flow;
- accelerate the process of ADP creation;
- form the competency matching matrix of academic disciplines;
- provide the development of work programs with allowance for the sequence of the studied disciplines and the formation of competencies;
- analyze the interrelation of the disciplines involved in the process of the future specialists training;
- synchronize the list of recommended literature for mastering the discipline with the list of literature of the university library;
- provide the possibility of the working ADP individualization;
- reduce the number of mistakes made by teachers;
- automatically identify discrepancies and contradictions;
- track the requirements for the material and technical support of the learning process;
- ensure flexibility to changes in documents governing the development process;
- ensure that working programs comply with the requirements of Federal State Educational Standards for higher education;
- form working programs as separate editions;
- ensure the transparency of the processes of agreeing and approving the ADP formal and substantive parts;
- ensure storage, versioning, and accessibility of all working ADP versions;
- ensure a high level of quality management in developing the working ADP;
- ensure the working ADP availability to all participants in the educational process;
- ensure the collection of statistical data on the current status of the working ADP.

IS KEY ELEMENTS AND THEIR FUNCTIONALITY

When automating the ADP development process, it is necessary to implement the functionality to allowing both the creation and editing of the working ADP and its key elements:

- creating, editing, searching, and using off-the-shelf programs (provided they are available in the database);
- creating and editing templates of working ADP;
- filling the sections of the working ADP based on regulatory requirements;
- adding new documentation;
- ability to integrate with digital library catalogs;
- work with competencies (individually and by creating a common list) implying creation, editing, and automatic generation;
- formation of the teaching load, manually or automatically.

In view of the above, it has been decided to develop the proper module for working with ADP to be further implemented at RTU MIREA. The formalized description of functional requirements for the ADP module may be presented as shown in Fig. 3.

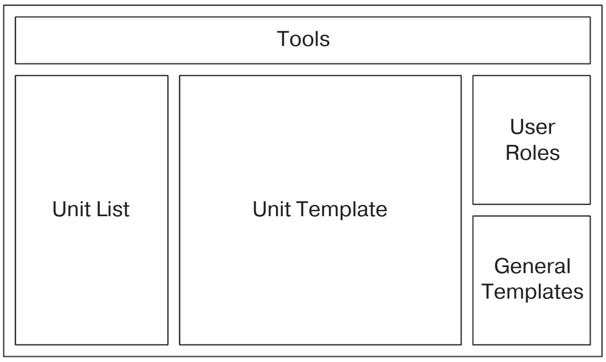

Fig. 3. Basic functionality of the ADP module for forming ADP approval templates

Tools provide the user with various functionalities including navigation between templates and printing. Unit List displays the hierarchical structure of units from Faculty to Department level. Unit Template contains information regarding the current template. User Roles contain links to reference information about ADP developers and those responsible on behalf of the Department and Methodology Department. General templates contain links to departmental programs.

The ADP module aims to solve the following set of tasks:

1. Storage of created and implemented learning programs indicating their versions.
2. Access to information about courses and their key characteristics for ATS.
3. Identification of the ADP place in the curriculum.
4. Ability to set the values assigned to the credits required for the student training areas and the corresponding specialization for each discipline.
5. Formation of the set of student competences to be acquired by him/her at the end of the study discipline.
6. Identifying the interrelationships of various disciplines in the curriculum.
7. ADP status allowing determining its presence or absence.
8. Determination of intersection cases of ADP sections with allowance for the chosen training areas and specialties.

By solving the described problems, three key requirements for the ADP development and implementation process are fulfilled: accessibility, interconnection, and transparency [14–16]. Access to the ADP created using the module is provided to all persons

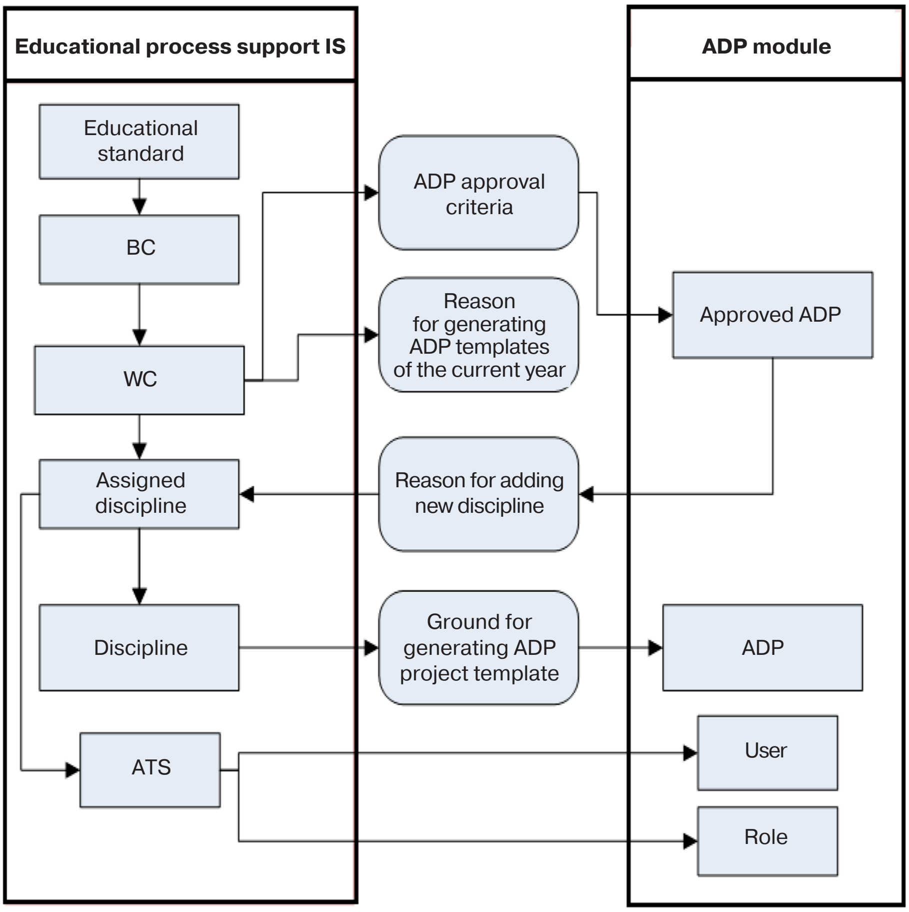

Fig. 4. Relationship between ADP attributes and entities inherent in the learning process. WC is working curriculum. BC is basic curriculum

involved in the educational process thus ensuring openness and transparency in organizing the learning process.

Universal templates for generating standard ADP forms can be divided into two main groups. The first group contains templates included in the work plan and assigned to a particular structural unit and ATS. Its main distinguishing feature is to indicate the presence of the university-wide elective. The second group is intended for templates only being planned to be introduced in the curriculum. Both typified groups of templates created at RTU MIREA in accordance with the classification of academic disciplines are accessible to ATS.

The structural content of the template includes two areas: a functional employee area and ADP area. The first provides the employee with access to their courses, material base, ADP, group chat, and additional tool features. The second area includes the following five tabs providing information between which the user can switch: ADP card, content, disciplines, review, and status log.

By integrating the module with IS, two main features are implemented:

- formation of the academic discipline parameters with the provision of connection between parameters conditioned by the curriculum and the sections of the selected discipline;
- availability of choice between different competences of the corresponding academic discipline for obtaining the necessary information formed on the basis of the data stored in the competence map and specialty direction (Fig. 4).

CONCLUSIONS

The implemention of the ADP module as a part of the learning process support IS at RTU MIREA reduces the time spent by ATS on the ADP development by providing users with various templates along with the possibility to fill them automatically in accordance with the discipline curriculum. The ADP module functionality also ensures the collection of statistical data on the program current status and the availability of all ADP versions, as well as increasing the student awareness level.

Authors' contributions

Ju.V. Starichkova has developed the functionality of the self-developed module “Academic Discipline Programs.”

I.E. Rogov has conducted an analysis of the links between the ADP and the key entities of the educational process.

V.S. Tomashevskaya made a classification of learning management systems according to various criteria, key requirements for academic disciplines and the structure of ADPs.

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