Analysis and Summarization of the Experience of Developing Adaptive Learning Systems in Higher Education

Kateryna P. Osadcha[1][a], Viacheslav V. Osadchyi[1][b], Vladyslav S. Kruglyk[1][c] and Oleg M. Spirin[2,3][d]

[1]*Bogdan Khmelnitsky Melitopol State Pedagogical University, 20 Hetmanska Str., Melitopol, 72300, Ukraine*

[2]*University of Educational Management, 52A Sichovykh Striltsiv Str., Kyiv, 04053, Ukraine*

[3]*Institute for Digitalisation of Education of the National Academy of Educational Sciences of Ukraine, 9 M. Berlynskoho Str., Kyiv, 04060, Ukraine*

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Abstract: The article provides a brief analysis and summarization of the existing experience of developing adaptive learning systems in higher education. Existing models of adaptive learning systems, which are necessary for the educational process in higher education, are analyzed. Conclusions are made as for the requirements for the design and modeling of the author's adaptive system of future specialists' professional training in a blended learning environment. The main ones are requirements for the approaches to modeling, types of adaptation implemented in the system, ways to ensure individualization and personification in the process of both face-to-face learning and learning with the help of information and communication technologies.

1 INTRODUCTION

In terms of socio-economic and evolutionary changes in the society, science and technology modern educational process in higher education requires appropriate changes (Ryabinova, 2009) and modifications of learning strategies. Among promising and relevant technologies in education today there are adaptive learning technologies that help the educational system to adapt to the specific features and needs of a student and are typically controlled by the computational devices, adapting content for different learners' needs and sometimes preferences (Shute and Zapata-Rivera, 2007). With the rapid development of the artificial intelligence in education (Abuselidze and Mamaladze, 2021), adaptive learning system has become the trend of web-based e-learning system (Chen and Zhang, 2008).

Research and implementation of adaptive learning technologies has contributed to the development of the adaptive learning system. Adaptive learning system is a platform for individual learning, which uses different techniques of artificial intelligence to adapt instruction to the learner's individual differences, such as the learning ability, preferences, learning style and learning goal etc. (Chen and Zhang, 2008).

Since the emergence and development of adaptive learning technologies, scientists have proposed various models of adaptive learning systems: KFS (Knowledge Flow Structure), which is based on the concept of knowledge flow (Kurgan, 2013); DCM (Dynamic Content Model), which uses a concept map for the organization and presentation of knowledge (Kristensen et al., 2007); model, designed by Solovov (Solovov, 2010), the main concepts of which are the educational element, content graph and specification of educational elements (de Marcos et al., 2007); CDCGM (Competency-Driven Content Generation Model), which is focused on the availability of all training materials for the electronic training course developer; this materials are stored in the form of educational units related to the competence bank; SHM (Structural-Hierarchical Model), which provides tools for describing the didactic structure of educational units (Silkina and Sokolinsky, 2016). On the other hand, Oxman and Wong (Oxman and Wong, 2014)

[a] https://orcid.org/0000-0003-0653-6423
[b] https://orcid.org/0000-0001-5659-4774
[c] https://orcid.org/0000-0002-5196-7241
[d] https://orcid.org/0000-0002-9594-6602

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prove that the use of adaptive learning in higher education has been slower to develop, and challenges that likely contributed to slow adoption remain. It is facilitated by partnerships between publishers and adaptive learning companies. In 2010, Knewton expanded beyond its initial GMAT prep product to partner with large universities to create adaptive remedial math education courses. In 2013 Career Education Corporation partnered with CCKF (international education technology firm) to build 300 adaptive courses using its adaptive learning system RealizeIt. In 2017, the University of Central Florida and Colorado Technical University partnered with RealizeIt to explore how best to use an adaptive learning platform to increase student success (Dziuban et al., 2017).

Despite the development of adaptive technologies, a review of previous research works has shown that a system that combines the capabilities of adaptive technologies, individualization and personification in the conditions of blended learning in a higher educational institution has not been modeled and developed yet. Such a system is needed to improve the training of future professionals, which is becoming more technological, student-centered and variable. In order to develop a new adaptive learning system, it is advisable to analyze and summarize the existing experience of adaptive learning systems development in higher education. This is the aim of our research, oriented for the identification of the requirements for the design and modeling of our own adaptive learning system for future professionals' training in a blended learning environment.

2 METHODS OF THE STUDY

Methods of research:

- methods of specification and systematization of theoretical knowledge were used for the development of the research objectives
- methods of analysis and summarization of psycho-educational, specialized and technical sources on the use of adaptive learning technologies in order to identify the structure and characteristics of existing adaptive learning systems and requirements for our own adaptive system of individualization and personification of future professionals' training in a blended learning environment.

3 RESULTS

3.1 Analysis of Existing Adaptive Systems in Higher Education

Using the search tools of Google Scholar, ERIC, Web of Science and Scopus, we were searching for scientific papers on the development of adaptive learning systems which could be used in higher education. We highlighted those that were publicly available: 60,462 – in ERIC, 92 – in Web of Science, 183 – in Scopus. Of the 2,780,000 articles in Google Scholar, we singled out articles by Russian and Ukrainian authors. We analyzed studies representing the development of adaptive learning systems (platforms) in higher education.

Burdaev (Burdaev, 2006) proposed an adaptive system EOS "KARKAS", which is aimed at training and testing of students of economic specialties. It includes the following components: an output machine to provide training; output machine for adaptive testing; learner error analyzer. This system contains a number of models: 1) a model of learning, characterized by the following parameters: learning objectives; types of errors occurring during the assessment tasks execution; time of the assessment tasks execution; need for assistance while executing a task; 2) models of the learners, characterized by the following parameters: psychological type of students' behavior; level of students' intellectual development; level of readiness for the subject under research; motivation. The adaptability of learning in EOS "KARKAS" is realized in the fact that at each checkpoint a selection of the learning model takes place depending on the level of learner's knowledge. As a result, such parameters as sequence, depth and forms of content presentation are modified.

The structure of Pedagogically Adaptive Learning System based on Learning Styles, designed by Siadaty and Taghiyareh (Siadaty and Taghiyareh, 2007), includes the domain knowledge module, the learner model, the pedagogical module and the interface module (figure 1).

The domain model is a knowledge representation of the materials that the learner has to learn and includes a set of domain concepts such as facts, lessons and problems forming a kind of semantic network. The learner model is a hybrid model, i.e., it consists of a stereotype model (which classifies the learners based on their entry behaviors or characteristics) and an overlay model (which is used to represent users' knowledge of the concepts of the subject domain). The pedagogical module assumes responsibility for making decisions about what will be learned, how it

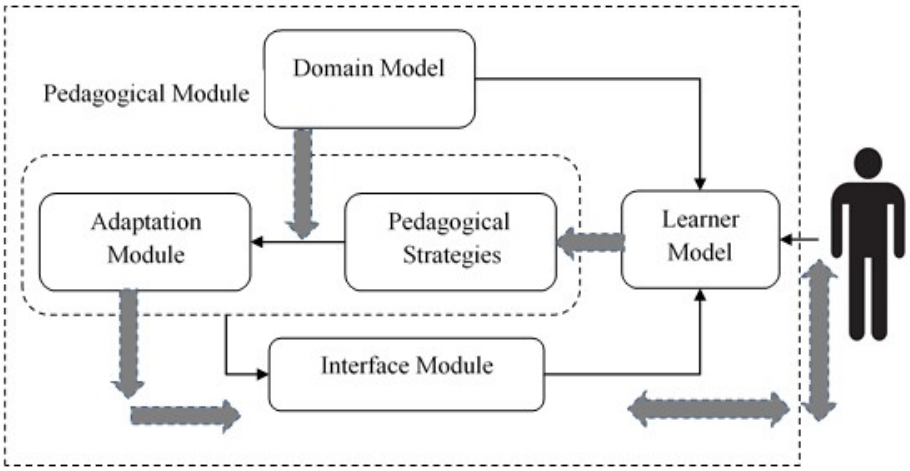

Figure 1: Architecture of the system (Siadaty and Taghiyareh, 2007).

will be learned, when it will be learned. The interface module delivers the personalized contents to the learners and receives their feedback as well.

The adaptive learning system, proposed by Chen and Zhang (Chen and Zhang, 2008), is oriented for learning style and cognitive state. Its architecture is comprised of the media space, domain model, learner model, instruction model, adaptive model and user interface. Media space includes the instructional resources database (all kinds of teaching materials, such as text, picture, audio, video, cartoon, etc.) and instructional resources description models (teaching resources by SCORM standard). Domain Model is the repository of storing and structuring the instructional content in the particular domain, such as a course. Domain Model includes the learning objectives hierarchy and domain ontology. Learner Model is used to provide a foundation for diagnosing the learning process, providing the adaptive learning support for learners. Instruction Model is used to simulate the teacher's teaching strategies; it stores the specific teaching rules. Adaptive model stores the adaptive rules of the system, including the content adaptation rules and adaptive navigation support rules. User Interface provides the interaction function between learners and adaptive learning system.

The adaptive distance learning system, proposed by Gorohovskiy and Troyanovskaya (Gorohovskiy and Troyanovskaya, 2015), includes the following modules: module for collecting data on student's activities (to provide primary data on direct and indirect assessment); module for issuing methodical materials, which directly displays a lecture or practical materials; automatic module for data processing and issuance of material for processing primary evaluation data and appropriate selection of training materials and assessment elements (figure 2). In this composition, it suits the peculiarities of student's perception of educational material.

Red (Red, 2010) described RATOS-AI, an intelligent adaptive system for the development and maintenance of distance learning courses, consisting of the following elements: 1) module for each role of a teacher (teacher-methodologist module, teacher-consultant or tutor module, teacher-designer of training courses module); 2) core IASDL of RASOS-AI; 3) four knowledge bases (subject area, separate academic course, reference model of knowledge, current model of pharmacist's knowledge), database of training protocols, database of electronic publications and database of training scenarios; 4) information system of monitoring of learning; 5) repository of educational elements; 6) training system and assessment system module; 7) systems of communication and access to the single information space of University, as well as the subsystem "Dean's Office".

The adaptive system of distance learning and knowledge assessment EduPRO, presented by Fedoruk (Fedoruk, 2010), includes a model of lecture material structuring, model of adaptive testing and a model of decision-making on transitions between levels of complexity in the adaptive testing system. The system makes it possible to organize the process of individualized learning, allowing teachers to form an individual structure of educational material and identify the moment of students' readiness for the transition to a more complicated level of material.

Information and training system ICT PROFF (Huang and Shiu, 2012) uses modified psychological tests adapted to the computer procedure of interviewing respondents with automatic calculation of the coefficients of personalized models of learning mate-

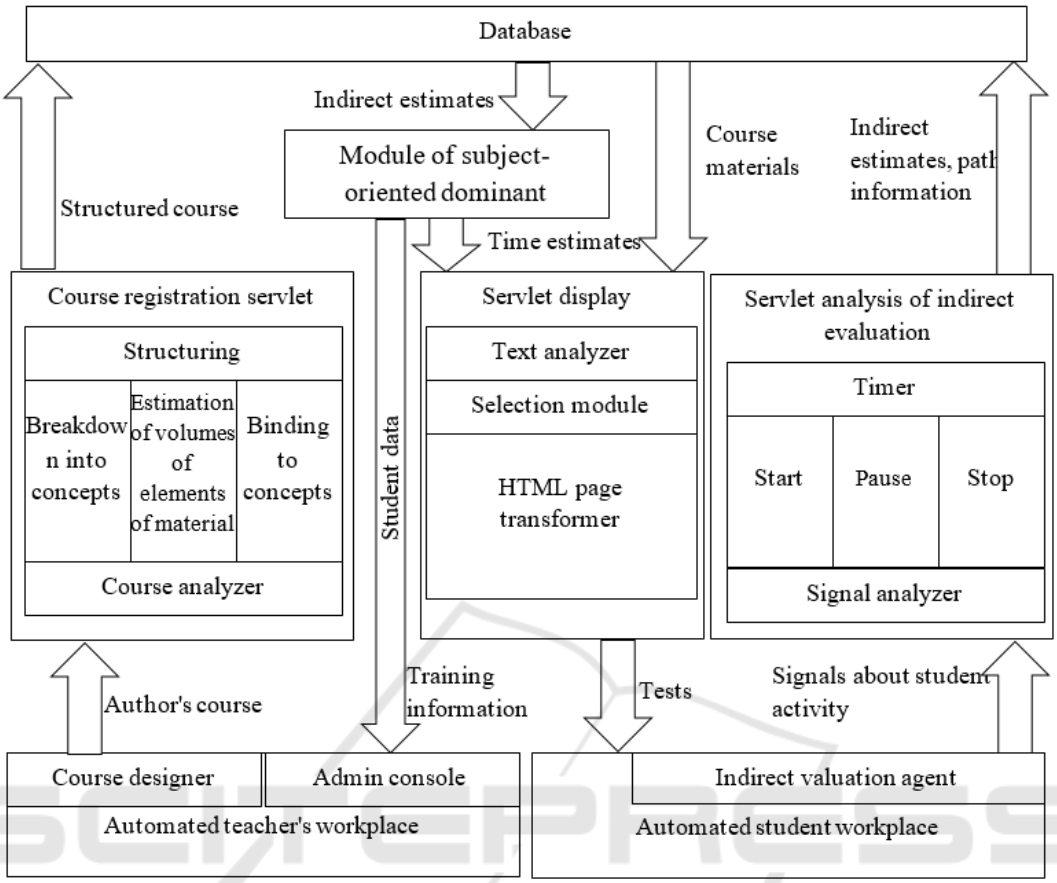

Figure 2: Technological structure of adaptive distance learning system (Gorohovskiy and Troyanovskaya, 2015).

rial and subsequent calculation of external support of the learning process. ICT PROFF system basically uses a modern intelligent CAD software environment MVTU version 3.0, designed for detailed analysis and study of dynamic processes in technical, economic and social systems. The developed adaptive system of personalized professional training of students allows building the predicted trajectories of knowledge mastering for each student that can be used for the formation of homogeneous educational groups.

User-centric adaptive learning system was designed by Huang and Shiu (Huang and Shiu, 2012). It uses sequential pattern mining to construct adaptive learning paths based on users' collective intelligence and employs Item Response Theory (IRT) with collaborative voting approach to estimate learners' abilities for recommending adaptive materials. Such adaptive learning, which is oriented for the user, is comparable to expert-designed learning and learners are more satisfied and learn efficiently. The system architecture is illustrated in figure 3.

Vlasenko (Vlasenko, 2014) has described an adaptive distance learning system in the field of information technology, which is based on the basic components used in existing distance learning systems, namely: blocks (diagnostics of the initial level of knowledge, formulation of learning objectives, design and correction of curriculum, testing, model design, formation of educational elements, correction of model, assessment of achievements); databases (personal test tasks, entry-level test knowledge tasks, test tasks to assess learning outcomes), models (learner model, adaptation model). Adaptation of the system to the learner is carried out on the basis of a model which, in addition to standard parameters, includes such parameters as the degree of learning outcomes achievement, system of learner's advantages, individual curriculum, etc. Adaptation at the stage of planning teaching is carried out by developing a curriculum that, on the one hand, meets learner's needs and preferences and, on the other hand, provides training which is appropriate to the competency model and therefore meets the labor market requirements.

Yasuda et al. (Yasuda et al., 2015) offered adap-

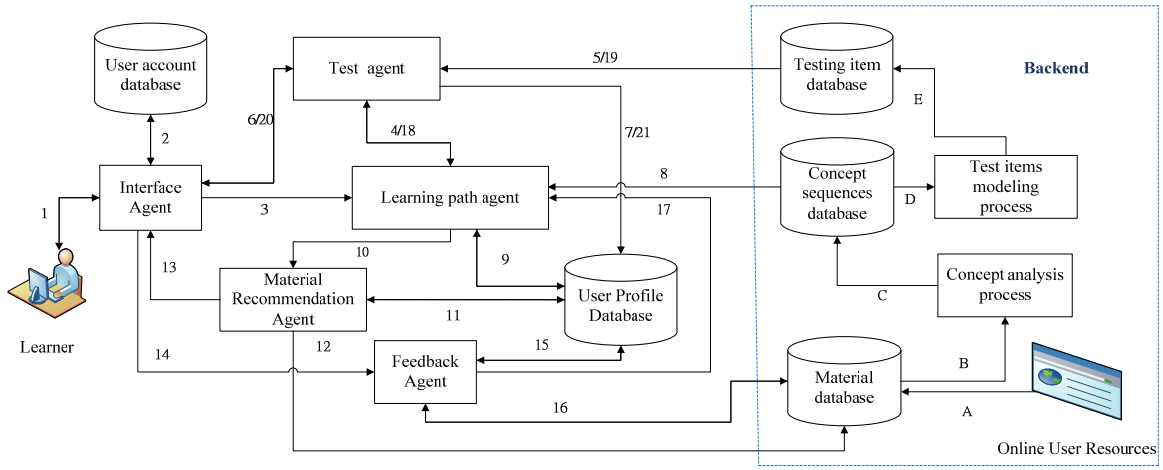

Figure 3: User-centric adaptive learning system architecture and operation procedure (Huang and Shiu, 2012).

tive learning system using a Bayesian network (figure 4). The system has 2 modes: testing mode and learning mode. The testing mode gauges learners' understanding in each course unit using the Expected Value of Network Information (EVINI)-based adaptive testing scheme. In the proposed system, the learning mode assigns each learner drills on course units that the learner is not good at. The Bayesian net framework is used to calculate expected value of network information. The configuration of the proposed system includes such structural elements: the WEB application server that runs HTML5-based drill contents for both modes; Bayesian net server that infers the probability that the learner has understood each of the not-yet-set units, by examining the accuracy of previous answers; the database server that stores learners' logs, which contain each learner's drill answers.

The developers included the following elements into the adaptive information learning system (Fedusenko et al., 2017): a subsystem of learning (subsystem of working with D-graph, subsystem of working with student model), subsystem of knowledge assessment (subsystem of task design, subsystem of assessment), knowledge base and database. Its use allows increasing the efficiency and quality of education by selecting an individual learning path for each student.

To study a foreign language, an adaptive automated system "Arcturus" was developed (Skliarova, 2016). It solves a number of tasks related to the automation of the processes of foreign language competence development. The system has the following features: differentiation of its elements according to the level of complexity; automation of the process of test tasks design with different levels of complexity; multi-criteria methods for the evaluation of education quality; methods for evaluating student's psychophysical characteristics while learning with the help of this system; tools for modeling the process of student's individual path in learning a foreign language; methods for enhancing the quality of optimal control of the individual learning path; tools of control flow statement of educational process of system; development of algorithm of system functioning.

The system, proposed by Shershneva et al. (Shershneva et al., 2018), is aimed at teaching mathematics. This system consists of a subject area module, user model (information about student, which is needed to adapt educational content to his or her individual characteristics and monitor the learning process in the electronic environment), adaptation model (automated navigation system and adaptation of educational content based on learner's individual characteristics), and model of learning outcomes assessment (identification of the level of student's subject competence through the assessment of all its components) (figure 5). The authors of this system state that it is a universal system and it can serve as a basis for the organization of adaptive learning in the electronic environment not only in the field of mathematics but also in other disciplines of educational programs in various fields of training in secondary, higher and extracurriculum education.

According to Toktarova and Fedorova (Toktarova and Fedorova, 2020) in order to train students in mathematics in the information-educational environment it is recommended to introduce such adaptive system which is based on the adaptation of training to students' individual features, management of learning process in the information-educational environment, use of mobile devices for training, and a

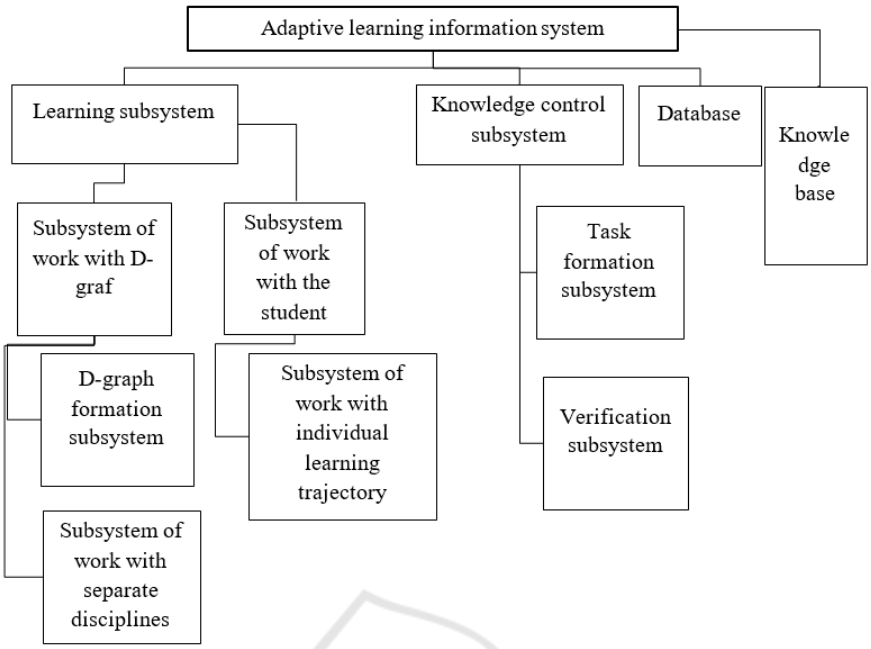

Figure 4: Conceptual model of adaptive information system (Yasuda et al., 2015).

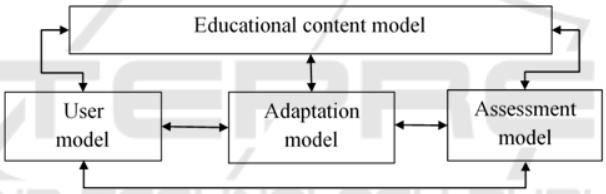

Figure 5: Structural scheme of the adaptive system of web-based teaching (Shershneva et al., 2018).

set of educational-methodological and technological means.

3.2 Identification of Requirements for an Adaptive System of Individualization and Personalization of Future Specialists' Professional Training in a Blended Learning Environment

Based on the analysis of the above mentioned models of adaptive systems, we have identified the following requirements for an adaptive system of individualization and personalization of future specialists' professional training in a blended learning environment. The system should:

1) be based on polyparadigmatic and systematic approaches to its modeling, which involve the use of an open cluster of approaches to learning, their integrated application in a structure of interconnected subsystems;
2) provide the adaptation of educational materials, learning outcomes monitoring, devices (PC, smartphone, tablet computer), and face-to-face classes to the students' individual characteristics;
3) enhance a learner-centered approach in the process of both face-to-face learning and learning with the help of information and communication technologies; in order to implement this system the following should be done: automated study of student's individual features, tutoring and support of student's individual educational program, individualization of learning process, development of student's individual features and his or her new characteristics according to personal educational needs, monitoring and recording of student's individual progress;
4) provide the personalization of the electronic educational environment as well as learning environ-

ment;

5) include both modern educational technologies (interactive methods, intensification, project work and creative learning, etc.) and information and communication technologies (distance learning technologies, analysis and processing of big amount of data) for future specialists' professional training in a higher educational establishment;
6) include subsystems that characterize certain areas of future professionals' training (adaptation, individualization, personalization of training) and reflect the mixed nature of training;
7) be implemented as a working prototype of an adaptive system for different groups of stakeholders and use an adaptive system for individualization and personalization of future professionals' training in a blended learning environment.

Based on the analysis of the existing adaptive technologies (Osadcha et al., 2020) and ICT for individualization (Kruglik and Chorna, 2020) and personification (Osadchyi and Krasheninnik, 2020) of training and in order to implement the requirements for the system, we can conclude that it is appropriate to implement the following learning tools in an adaptive system of individualization and personalization of future specialists' professional training in the context of blended learning: Moodle platform and plug-ins for adaptive learning, capabilities and properties of Moodle for the implementation of individualization of learning (competence module and progress block, tools for imposing necessary restrictions on learning elements, means of multicriteria assessment, tools for multivariate presentation of educational information, etc.), a set of information and communication technologies and modern technical means of learning to ensure the personification of learning. This will allow us to design an adaptive system of individualization and personalization of future professionals' professional training in a blended learning environment, which will consequently promote the impact of distance technologies on the improvement and intensification of learning in higher educational institutions.

4 CONCLUSIONS

Analysis of adaptive learning systems and their models showed that these solutions have a narrow applied character (teaching mathematics, languages or teaching students of a particular specialty). They do not contain all necessary elements for educational process organization or do not have the structural elements and functional features required by teachers and students in the modern educational process. We have also generalized the requirements for the adaptive system of individualization and personalization of future specialists' professional training in the conditions of blended learning. These requirements are as follows: system modeling has to be done according to polyparadigmatic and systematic approaches; it should take into account the tasks of adaptation, individualization and personalization of future professionals' training; the system should be structured in accordance with the functional purpose of its elements; the system should be implemented in the form of a working prototype based on the Moodle platform tools. The adaptive learning system should be easy to use in the process of learning, have an intuitive interface and appropriate structure, as well as the tools which are necessary for future professionals' effective training.

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