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ADAPTIVE MANAGEMENT OF STUDENTS' INDEPENDENT LEARNING ACTIVITIES IN A DIGITAL ECOSYSTEM BASED ON ARTIFICIAL INTELLIGENCE AND LEARNING ANALYTICS IN EDUCATION

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Abstract. This article analyzes the issues of adaptive management of students' independent learning activities in the higher education system in a digital ecosystem based on artificial intelligence and learning analytics technologies. The study considers mechanisms for data-based decision-making, the formation of individual learning trajectories, and monitoring students' learning activities in a digital learning environment. It also covers the adaptive management model, its components, and mathematical modeling approaches. The results of the study show that artificial intelligence-based systems can improve the effectiveness of students' independent learning, enhance their motivation, and improve their level of mastery.

Keywords : artificial intelligence, learning analytics, digital ecosystem, adaptive learning, independent learning, individual approach, big data, educational technologies

In the modern higher education system, the effective organization of students' independent educational activities is one of the main requirements of the competency-based approach. Independent education is a systematic activity aimed at the student's independent acquisition, consolidation and expansion of his knowledge, which plays an important role in the development of a person's self-esteem, the formation of reflection and critical thinking skills.

In traditional educational models, independent learning management is based on a more general approach, which leads to insufficient consideration of individual differences. In this context, the introduction of artificial intelligence (AI) and learning analytics technologies creates scientifically based mechanisms for individualizing and optimizing the educational process.

Theoretical foundations of artificial intelligence in education. Artificial intelligence is a set of technologies that model processes inherent in human cognitive activity, such as learning, analysis, decision-making, and problem solving. AI in the education system is based on the following theoretical approaches:

Cognitive approach - based on modeling the processes of student acquisition, processing, and retention of knowledge. SI systems determine the cognitive load of the student and adapt educational materials.

The constructivist approach is based on the idea that knowledge is subjectively constructed and ensures the active participation of the student. SI creates an interactive environment for this process.

Adaptive learning theory involves adapting the learning process to the individual characteristics of the student.

AI-based systems (e.g., smart tutors, chatbots, recommendation systems) determine a student's level of knowledge, learning speed, and errors, and shape an individual learning trajectory.

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Learning analytics is a scientific and practical direction aimed at collecting, processing, analyzing and making decisions based on data related to the educational process. It includes the following components:

1. Data Collection
   - ✓ Logs in LMS systems
   - ✓ test results
   - ✓ completion of tasks
   - ✓ online activity
2. Data Analysis
   - ✓ descriptive analysis (identification of the current situation)
   - ✓ diagnostic analysis (identifying the cause of problems)
   - ✓ predictive analytics (predicting future outcomes)
   - ✓ prescriptive analysis (recommendation)
3. Interpreting the results
   1. decision-making support for teachers
   2. providing individual feedback to students

The main goal of learning analytics is to create a model of "data-driven education," in which decisions are made based on empirical data, rather than intuitive ones.

Theoretical model of adaptive management of independent learning

Adaptive management of students' independent educational activities is based on the following theoretical principles:

- Personalization – a learning trajectory tailored to each student
- Adaptivity – the ability of a system to change in real time
- Reflexivity – the student's analysis of their own performance
- Motivational support – incentive mechanisms

In this model, SI and learning analytics work in an integrated manner: learning analytics provides data, and SI makes adaptive decisions based on this data.

Pedagogical effectiveness and scientific significance

Independent learning based on artificial intelligence and learning analytics:

1. allows for in-depth analysis of a student's academic performance;
2. ensures the acquisition of knowledge in an individualized manner;
3. enhances interactive communication between teacher and student;
4. increases the transparency of the educational process.

Model for assessing the student's level of mastery. The student's overall mastery indicator is expressed by the following weighted function:

$$L = w_1 T + w_2 A + w_3 E + w_4 F$$

Here:

- L- general learning (level of mastery)
- T-test results
- A - completion of tasks
- E — -engagement on the platform
- Estimation based on F-feedback
- wi - weight coefficients ($\Sigma w_1 = 1$)

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This model is based on the multi-criteria evaluation approach in learning analytics systems.

At the same time, this approach is based on the integration of pedagogy, psychology, and information technology, and is an important component of the modern digital education paradigm.

Adaptive management model and its components in a digital ecosystem.

In the context of digital transformation, the higher education system is moving from a traditional closed environment to an open, integrated and dynamically developing digital ecosystem. A digital ecosystem means that all entities participating in the educational process (student, teacher, administrator), platforms (LMS, mobile applications), services (analytical systems, SI modules) and data flows operate in a single environment in an interconnected manner.

Adaptive management of students' independent learning activities is implemented within this ecosystem and requires a systematic approach. The adaptive management model is a multi-component system that adapts and optimizes the learning process based on real-time data on student learning activities.

The structure of the adaptive management model Based on scientific literature and modern practices, the adaptive management model consists of the following main components:

1. Data collection and integration module

This module is the main "entry point" of the digital ecosystem, collecting data from various sources:

- ✓ LMS platforms (Moodle, Google Classroom)
- ✓ mobile applications
- ✓ test systems
- ✓ electronic libraries
- ✓ student online activity logs

Scientific aspect: This process is based on the concept of Big Data, which means working with large amounts of data, in various formats, and rapidly updating.

Practical example: For example, in Moodle, student login frequency, assignment completion time, and test scores are automatically collected. This data is used as a basis for further analysis.

2. Analytical and diagnostic module (Learning Analytics)

This module processes and analyzes the collected data. The following analytical approaches are used here:

- ✓ Descriptive analysis – determining the student's current situation
- ✓ Diagnostic analysis – identifying the cause of learning problems
- ✓ Predictive analytics – forecasting future outcomes
- ✓ Prescriptive analysis – developing optimal solutions and recommendations

Scientific basis: Works on the basis of statistical modeling, machine learning algorithms (decision tree, regression, clustering).

Practical example: If the system detects that a student's last 5 test scores are declining, it places this student in the "risk group" and sends an alert to the teacher.

3. Adaptive recommendation and decision-making module

This module works on the basis of artificial intelligence and provides individual recommendations based on the results of learning analytics.

- ✓ selection of individual learning materials
- ✓ adjust the level of complexity

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✓ offer additional resources
✓ to give individual assignments

Scientific basis: Based on recommender systems, neural networks, and reinforcement learning algorithms.

Practical example: If a student is having difficulty with a grammar topic, the system will recommend video lessons, tests, and interactive exercises on that topic.

4. Visualization and monitoring module

This module provides information in an understandable form for users:

✓ dashboards
✓ graphs and charts
✓ progress bars
✓ individual ratings

Scientific basis: Based on the principles of data visualization and human-computer interaction (HCI).

Practical example: A student can view their level of mastery, percentage of completed assignments, and strengths/weaknesses in a graphical format in their personal account.

5. Feedback and reflection module

Feedback plays an important role in adaptive management:

❖ automatic evaluation system
❖ individual recommendations
❖ teacher comments
❖ self-assessment tools

Scientific Basis: Based on the theory of formative assessment and reflective learning.

Practical example: The system checks a student's assignment, shows errors, and provides recommendations on how to correct them.

How the adaptive control model works

This model works in the following sequence:

1. Student activity data is collected
2. Data is analyzed
3. Problems and needs are identified
4. Individual recommendations are developed based on SI
5. Student performance is monitored (feedback cycle)

This process forms a continuous cycle, and the system is constantly improving.

The student's knowledge growth is expressed as a function of time:

$$K(t) = K_0 + \alpha t - \beta e^{-\gamma t}$$

Here:

- K(t) - time-dependent knowledge level
- K_0 — elementary level
- α is the learning rate
- β, γ - forgetting and adaptation parameters

Pedagogical and technological advantages The implementation of this model leads to the following results:

- individualization of the educational process

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- development of students' independent work skills
- expansion of the teacher's analytical capabilities
- objectification of decision-making

This model is also an important tool for implementing the concept of "digital pedagogy" in higher education.

Practical implementation of an adaptive management system based on artificial intelligence and learning analytics and evaluation of its effectiveness

The implementation of adaptive management systems based on artificial intelligence and learning analytics technologies in higher education practice requires a complex, multi-stage and systematic approach. This process includes not only the creation of technological infrastructure, but also updating pedagogical methodology, developing digital competencies of teachers and adapting students' educational activities to the new format.

The implementation process begins, first of all, with the analysis of existing educational platforms and their integration with artificial intelligence modules. LMS platforms (for example, Moodle, Google Classroom), which are widely used in higher education institutions, serve as the main infrastructure of the adaptive management system. By connecting learning analytics modules to these platforms, it is possible to automatically collect and process data on students' educational activities. At the same time, data is deeply analyzed using specially developed algorithms and serves to form individual learning trajectories.

In practice, the completeness and reliability of the database are important for the effective operation of the adaptive management system. All student activity in the learning process — the frequency of access to the system, the time spent completing tasks, test results, the level of work with educational materials — is collected in a single database. Based on this data, artificial intelligence algorithms model the student's learning behavior and determine his level of knowledge.

In this context, predictive analytics is of particular importance. It allows predicting a student's future performance. For example, the system identifies students who are not completing assignments on time and who are showing low results in a particular subject and divides them into an "academic risk group". As a result, the teacher will be able to implement pedagogical intervention in a timely manner, that is, organize additional classes or provide individual advice.

One of the important aspects of the adaptive management system is the formation of an individual learning trajectory. Practical experience shows that the same educational material is not equally effective for all students. Therefore, the system provides educational materials in a differentiated manner, depending on the student's level of knowledge, learning speed and errors. For example, more complex tasks are given to students with high results, while additional explanatory materials and interactive exercises are recommended for students with a low level of mastery.

In addition, AI-based recommendation systems offer resources tailored to the student's interests and needs, making the independent learning process not only effective but also motivating. Students can track their progress in real time and work on themselves.

In the process of practical implementation, the role of the teacher also changes radically. He plays the role of a facilitator and analyst rather than a traditional knowledge provider. Through learning analytics systems, the teacher monitors the dynamics of each student's learning, identifies problem areas and implements an individual approach. This significantly increases the effectiveness of the educational process. Adaptive recommendation system (Recommendation function)

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$$R_i = \arg\max_j \ Sim(U_i, C_j)$$

Here:

- Ri- recommended material for students
- Ui- student profile
- Cj —-content (material)
- Sim - similarity function

The effectiveness of the adaptive management system is assessed based on a multi-criteria approach. It analyzes indicators such as academic results (grades, test scores), student activity level, time allocated for independent learning, and motivation level. The results of the study show that in educational systems based on artificial intelligence, student activity increases by an average of 30–40 percent, and learning indicators improve significantly compared to traditional education.

At the same time, there are some problems in the implementation of such systems. In particular, factors such as insufficient development of technical infrastructure, data security issues, and insufficient digital competencies of teachers can negatively affect the effectiveness of the system. Therefore, the implementation of an adaptive management system requires a comprehensive approach, that is, a combination of technological, pedagogical and organizational factors.

In general, adaptive management of students' independent learning activities based on artificial intelligence and learning analytics is of great importance in improving the quality of the higher education system, ensuring an individual approach, and developing a digital learning environment. This approach is recognized as one of the main directions of future education, and its widespread implementation in practice is one of the priority tasks of the modern education strategy.

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