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METHODOLOGY FOR MONITORING STUDENTS' KNOWLEDGE LEVEL USING ARTIFICIAL INTELLIGENCE

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Abstract

This article provides a comprehensive theoretical and practical analysis of a methodology for monitoring students' knowledge levels based on artificial intelligence technologies. Within the scope of the study, the limitations of traditional assessment methods (tests, written examinations, and exams) are substantiated, particularly their inability to fully reflect students' actual knowledge level, learning dynamics, and individual learning trajectories.

At the same time, a conceptual model of AI-based monitoring systems is developed, and its structural components—learner model, domain model, instructional model, and adaptation mechanism—are analyzed in an integrated manner. Within this framework, the possibilities of real-time tracking of student activities using learning analytics technologies, processing large-scale educational data (big data), and forecasting are highlighted.

The study also develops methodological foundations for forming individual learning trajectories based on adaptive learning principles, dynamic assessment of knowledge levels, and automated decision-making mechanisms. Furthermore, the potential of AI tools to improve accuracy, reliability, and objectivity in assessing students' knowledge levels is justified through experimental results.

The findings indicate that AI-based monitoring systems not only significantly enhance the effectiveness of student assessment but also contribute to the individualization of the learning process, optimization of learning activities, and comprehensive improvement of education quality.

Keywords: artificial intelligence, knowledge monitoring, adaptive learning, learning analytics, educational technologies, individualized approach.

Introduction

In the 21st century, the global education system is actively undergoing a process of digital transformation. In this process, the rapid development of information and communication technologies—especially artificial intelligence (AI)—and their widespread integration into educational practice are significantly influencing the content, forms, and methods of education. AI-based systems are emerging as an important factor in personalizing the learning process, adapting to students' individual characteristics and levels of mastery, and improving the overall effectiveness of instruction.

In modern education systems, monitoring students' knowledge levels is an integral component of quality management. The monitoring process is important not only for assessing learning outcomes but also for tracking the dynamics of learning activities, identifying learning difficulties at an early stage, and developing individualized learning strategies. In this regard, the accuracy, objectivity, and adaptability of monitoring systems are among the key criteria determining educational effectiveness.

However, traditional monitoring methods—such as tests, written assignments, and final examinations—often fail to fully reflect the depth of students' knowledge, their cognitive engagement, and individual differences in the learning process. These methods are primarily focused on evaluating final outcomes and are not capable of providing real-time analysis of the learning process. As a result, the timely identification and resolution of problems arising during the educational process become limited.

Therefore, the development and implementation of AI-based monitoring systems in modern education are considered one of the most relevant scientific and practical challenges. Such systems enable the processing of large volumes of educational data (learning data), real-time analysis of students' learning activities, dynamic assessment of their knowledge levels, and the formation of individualized learning trajectories. Consequently, this leads to a significant improvement in the efficiency and overall quality of the educational process.

Literature Review

The analysis of scientific literature indicates that AI-based educational systems have, in recent years, become one of the most actively developing areas at the intersection of pedagogy and information technology. In particular, modern studies interpret the integration of artificial intelligence into the educational process as an important tool for personalizing learning activities, improving learning efficiency, and ensuring the objectivity of knowledge assessment.

Adaptive learning systems enable the dynamic adjustment of educational content and task complexity according to learners' individual characteristics—such as their level of knowledge, learning pace, interests, and cognitive styles. Such systems support the organization of a learner-centered educational process.

Learning analytics technologies, in turn, provide opportunities to monitor students' learning activities in real time by collecting, processing, and analyzing large volumes of educational data generated during the learning process. Through these technologies, it becomes possible to conduct an in-depth analysis of students' learning dynamics, error patterns, and behavioral characteristics, as well as to develop predictive models.

In addition, Intelligent Tutoring Systems, based on AI algorithms, perform functions such as assessing students' knowledge levels, providing personalized recommendations, and supporting independent learning processes. These systems contribute to improving educational efficiency by automating certain functions traditionally performed by teachers.

Many researchers emphasize that for AI-based educational systems to function effectively, their architecture should be based on the following key components:

1. **Learner Model** — represents the student's knowledge level, individual characteristics, learning style, and learning dynamics;
2. **Domain Model** — reflects the structure of knowledge within a subject area, including relationships between concepts and content units;
3. **Instructional Model** — defines the didactic basis that shapes teaching strategies, methods, and educational decisions;
4. **Adaptation Engine** — a decision-making system that personalizes the learning process based on the above models.

The integration of these components enables AI-based educational systems to achieve high efficiency in assessing, monitoring, and developing students' knowledge.

Methodology

To achieve the research objectives and tasks set in this study, a комплексный (comprehensive) approach was applied, incorporating several scientific research methods:

- **Theoretical analysis method** — scientific sources in the fields of artificial intelligence, adaptive learning, learning analytics, and educational monitoring were thoroughly studied

and analyzed to determine the theoretical foundations of the problem. This method made it possible to generalize existing scientific views and form the conceptual basis of the research.

- **Comparative method** — a comparative analysis was conducted between traditional assessment systems and AI-based monitoring systems, highlighting their differences, advantages, and limitations. This allowed for a scientifically grounded evaluation of the effectiveness of the new approach.
- **Experimental method** — to determine the practical effectiveness of the proposed methodology, a pedagogical experiment was conducted using control and experimental groups. Students' knowledge levels were assessed through pre-tests and post-tests, and the impact of the AI-based monitoring system was examined.
- **Statistical analysis method** — the obtained experimental results were processed using mathematical and statistical methods to determine their reliability and significance. Final conclusions were drawn based on percentage indicators, growth dynamics, and comparative results.

The integrated application of these methods ensured the scientific validity, reliability, and objectivity of the research findings.

Monitoring System Model

The process of monitoring students' knowledge levels based on artificial intelligence is organized as a complex and multi-stage system, which includes the following main functional stages:

1. Data Collection

This stage represents the primary input component of the monitoring system, where diverse and significant data related to students' activities are systematically collected. In particular, this includes students' test results and assessment indicators, performance in practical and theoretical tasks, time spent on completing assignments and activity intensity, as well as interaction data with the system (such as login frequency, time spent on the platform, level of engagement, etc.).

The collected data serve as a crucial source of information for subsequent stages of the monitoring system. They are deeply analyzed using artificial intelligence algorithms to determine students' knowledge levels, evaluate their learning activities, and form individualized learning pathways. Thus, this stage creates the foundational data base necessary for further analytical processes.

2. AI-based Analysis

At the next stage, the collected data are analyzed using artificial intelligence technologies, particularly machine learning and data mining methods. During this process, students' errors are first identified and subjected to structural analysis, allowing for the determination of their causes and recurring patterns.

In addition, students' knowledge levels are evaluated both individually and at the group level, while the effectiveness of the learning process is analyzed through learning speed and dynamics. Furthermore, AI algorithms are used to analyze students' learning behavior, engagement levels, and to generate predictions about their future performance.

As a result of this analysis, an individual learning profile is created for each student, reflecting their knowledge level, learning characteristics, and academic activity. This profile serves as a critical foundation for personalizing the learning process in subsequent stages.

3. Adaptation

This stage represents the most important functional component of the AI-based system and is implemented based on the results of the previous analysis. At this point, the system creates

a personalized learning environment by taking into account each student's individual characteristics.

Specifically, individualized tasks and learning materials are recommended for each student, with the level of difficulty automatically adjusted according to the student's current knowledge level. At the same time, instructional strategies—such as repetition, reinforcement, or deepening of knowledge—are adapted based on the student's level of mastery. As a result, an individualized learning trajectory is formed for each student and is continuously updated.

This approach enables the organization of the educational process in a learner-centered manner, unlike traditional generalized models, and significantly enhances each student's learning efficiency.

4. Visualization of Results

At the final stage of the monitoring system, the obtained results are presented to users in a clear and user-friendly format. Specifically: learning dynamics are illustrated through graphs and charts; comparisons among students are carried out using ranking systems; individual progress is tracked through monitoring tools; and real-time data are provided to both teachers and students via dashboards.

The visualization of results facilitates decision-making processes and supports effective management of the educational process.

The integration of these stages ensures the effective functioning of an AI-based monitoring system. Through this approach, it becomes possible not only to assess students' knowledge levels but also to enhance them, optimize the learning process, and improve the overall quality of education.

Experimental Study and Analysis of Results

Within the framework of this study, an experimental investigation was conducted among higher education institution (HEI) students to evaluate the effectiveness of the developed AI-based monitoring methodology.

Experimental Design

A total of 60 students participated in the study and were equally divided into two groups:

- **Control Group** – 30 students (traditional teaching and assessment methods);
- **Experimental Group** – 30 students (AI-based monitoring system implemented).

Stages of the Experiment

The experiment was carried out in the following sequential stages:

1. **Pre-test (initial assessment)** – students' knowledge levels were assessed at the initial stage, and the equivalence between the groups was verified;
2. **Experimental learning process (8 weeks)** – the experimental group was taught using AI-based monitoring and adaptive learning systems, while the control group continued with traditional methods;
3. **Post-test (final assessment)** – at the end of the experiment, changes in students' knowledge levels were measured and comparatively analyzed.

Experimental Results

Group	Initial (%)	Final (%)	Growth
Control Group	56	68	+12%
Experimental Group	55	82	+27%

Analysis of Results

The analysis of the obtained results shows that although both groups demonstrated positive improvement in knowledge levels, the experimental group achieved a significantly higher growth rate (+27%). In particular, the experimental group outperformed the control group by 15% in terms of growth. The nearly equal baseline indicators (56% and 55%) confirm the

objectivity and reliability of the experimental results. At the same time, it was observed that the AI-based monitoring system had a positive impact on students' level of mastery, learning speed, and the quality of task performance.

Furthermore, the monitoring conducted during the experiment revealed important changes in students' learning activities. Specifically, students' independent learning skills improved, the speed of task completion increased, the number of errors decreased, and opportunities for structural analysis of these errors emerged. This, in turn, enables deeper analysis and more effective management of the educational process.

Overall, the results indicate that an AI-based monitoring system ensures high efficiency in improving the effectiveness of the educational process, accurately assessing students' knowledge levels, and supporting their individual development. These findings scientifically confirm that the proposed methodology is effective not only theoretically but also in practical application.

Conclusion

The use of artificial intelligence technologies for monitoring students' knowledge levels is emerging as one of the most promising and priority directions in modern education systems. The results of this study provide scientific evidence of the pedagogical effectiveness and practical significance of AI-based monitoring systems.

The analysis shows that AI-based monitoring systems ensure higher accuracy, objectivity, and efficiency compared to traditional assessment methods. At the same time, they enable the organization of learner-centered education by taking into account students' individual characteristics. The real-time operation of such systems allows continuous analysis of the learning process, tracking of learning dynamics, and early identification of emerging problems. As a result, the overall effectiveness of the educational process increases, and the quality of education improves comprehensively.

In addition, the use of AI technologies has proven to be an important tool for optimizing the learning process, supporting teachers' methodological activities, and enhancing students' independent learning. This makes it possible to manage the educational process more effectively without completely eliminating the human factor.

In the future, further improvement of AI-based monitoring systems, development of their algorithmic foundations, expansion of learning analytics capabilities, and integration with various educational platforms remain important scientific and practical tasks. At the same time, the widespread implementation of such systems will create broader opportunities for developing high-quality, efficient, and adaptive learning models within the digital education environment.

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