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Development and Implementation of An Adaptive Learning Model Based on Web3 Technologies in The Higher Education System

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Abstract: This article analyzes the possibilities of developing an adaptive learning model based on Web3 technologies (blockchain, smart contracts, tokenization, and decentralized applications) and implementing it in the higher education system. The study used mathematical modeling and systems analysis techniques to provide a learning experience tailored to the individual needs of students. The model provides for a correspondence between the level of knowledge of students and the complexity of educational materials, updating the level of knowledge based on a Bayesian model, storing assessment results on a blockchain network, and an incentive system through tokens. The experimental results showed that the Web3-based adaptive learning system increased the level of mastery by 18% and motivation indicators by 22%. Also, transparency in assessment and timely feedback mechanisms have built student confidence.

Keywords: Web3, adaptive learning, blockchain, smart contracts, tokenization, higher education, digital learning, motivation, transparent assessment, individualized learning.

Introduction: The rapid development of modern information and communication technologies is bringing about fundamental changes in the field of education. In particular, Web3 technologies — namely blockchain, smart contracts, tokenization and decentralized applications (dApps) — are having a significant impact not only on the financial and business sectors, but also on the education system. By the end of 2024, the number of startups based on Web3 technologies worldwide was expected to increase by 25%, and 15% of innovative projects in the field of education included Web3 platforms (Statista, 2024). At the same time, it was reported that the global education market size reached $7.3 trillion in 2023, of which about 9% was allocated to digital and adaptive learning technologies (HolonIQ, 2023).

Although traditional online learning systems have many advantages, they often fail to fully meet individual learning needs. Each student's level of knowledge, learning speed, and interests are different, so standardized online courses lead to a decrease in motivation in many students. At the same time, the transparency of the learning process and the fairness of assessment are also highlighted as urgent problems. It is precisely to overcome these shortcomings that there is a need to develop adaptive learning models using Web3 technologies.

Adaptive learning is a methodology that aims to provide a learning experience tailored to the individual needs of students. Web3 strengthens this process: using blockchain technology, student achievement levels, results, and grades are immutably stored, token-based motivation systems are created, and access to educational materials through decentralized platforms becomes more equitable and open.

According to a 2024 World Bank report, learning platforms built using Web3 technologies have an average of 27 percent higher retention rates than traditional online courses. Also, 35 percent of users found Web3-based learning systems more reliable than traditional online learning platforms.

In turn, the Ministry of Higher Education, Science and Innovation of the Republic of Uzbekistan approved the program "Digitalization of Education and Introduction

of Web3 Technologies" in 2023. Within the framework of this program, a number of projects are being implemented to test educational platforms based on Web3 technologies and develop adaptive learning models [1] [2].

The above factors indicate that by combining Web3 technologies and adaptive learning methodologies, significant results can be achieved in the education system. Therefore, this article examines the possibilities of developing an adaptive learning model based on Web3 technologies and implementing it in the higher education system.

METHODS

Systematic analysis methods to develop an adaptive learning model based on Web3 technologies. The adaptive learning model consists of the following main components: forming personal profiles of students, adapting educational materials, automatic analysis and assessment during the learning process, as well as transparent data storage and management through Web3 technologies.

The mathematical representation of the model assumes the following. Each student is designated by the number iii, and his knowledge level changes over time through the function Ki(t)K_i(t)Ki(t). The educational materials are represented by the level of complexity DjD_jDj. The condition for selecting suitable material for a student is expressed as follows:

selection condition:

| Ki(t)−Dj | ≤ d \text{selection condition: }

\quad |K_i(t) - Д_j| \leq \deltatanization condition: | Ki(t)−Dj | ≤ d

where δ \delta δ is the maximum allowable difference between the student's knowledge level and the complexity of the material.

An improved Bayesian model was used for the adaptive matching mechanism. The knowledge level for each student is updated as follows:

Ki(t+1)=Ki(t)+ a (Ri−Ei)K_i(t+1) = K_i(t) + \alpha (R_i - E_i)Ki(t+1)=Ki(t)+ a (Ri−Ei)

here:

- RiR_iRi — the student's real answer (0 or 1),
- EiE_iEi — the probability of the correct answer predicted by the system,
- α \alpha α is the learning rate coefficient.

The evaluation process and results are stored on the Web3 blockchain network in the following way: a transaction record is created for each evaluation result and this record is sent encrypted to all network nodes. This prevents the modification and concealment of the evaluation results.

In addition, a tokenization system has been developed to motivate students. Each student is awarded reward tokens (TiT_ iTi) when they successfully complete tasks or reach a new level of knowledge. The tokens are distributed as follows:

Ti= b *(Si)T_i = \beta \times (S_i)Ti= b *(Si)

here:

- SiS_iSi — the student's accumulated points,
- β \beta β is the coefficient relating tokens to points.

and rewards are automatically managed using blockchain-based smart contracts, ensuring the fair and transparent operation of the system.

To test the model, an experiment was conducted with 120 students. The students were divided into two groups: the first group was taught through the Web3 adaptive learning platform, and the second group was taught using traditional online learning methods. The learning process lasted 12 weeks, and knowledge measurement tests were conducted every week. Based on the test results, the learning trajectory of each student and the effectiveness of the platform were evaluated [3].

Ultimately, the Web3-based adaptive learning system showed an 18% increase in learning outcomes and a 22% increase in motivation. Transparency in assessment and timely feedback mechanisms also significantly boosted student confidence.

RESULTS

During the study, an adaptive learning model developed based on Web3 technologies was tested and compared with a traditional online learning system. According to the data studied, the Web3-based system had a significant positive impact on the learning process of students. In an experiment involving 120 students, students in the Web3-based group demonstrated an average of 18 percent higher learning outcomes at the end of the 12-week course. In the group that received traditional education, the learning outcomes were relatively lower.

In addition, the transparency of assessment results and timely feedback mechanisms provided by the Web3 platform had a positive impact on student motivation. Surveys were conducted to assess the level of motivation, and according to the results, a 22% increase in learning motivation was observed among students using the Web3 system. This confirms the effectiveness of blockchain technologies in rewarding

students with tokens and ensuring the immutability of results in the learning process [4].

At the end of the experiment, the dynamics of knowledge growth were studied. A knowledge curve was constructed based on the scores students scored at the end of each test. A smooth and stable growth in knowledge levels was observed in the group that studied using the Web3 system, while more fluctuations and instability were observed in the traditional education group. This clearly demonstrated the individual learning approach and real-time flexibility of the Web3 platform.

Data analysis showed that the average growth rate of knowledge in the Web3-based system was 5.3 percent per week, compared to around 3.1 percent in the traditional system. Also, the confidence interval constructed based on the assessment results was more stable and narrow in the Web3-based system, proving that the results were more reliable and accurate.

Immutable data storage based on blockchain, automatic grading using smart contracts, and increasing student motivation through a token system.

The experimental results were also statistically verified. When the t-test for mean differences was performed, the p-value was less than 0.01, which confirms that the effectiveness of the educational system created based on Web3 is statistically reliable.

In addition, the technical aspects of the system were also evaluated. When analyzing the performance of the Web3-based platform, the average confirmation time for blockchain transactions was 7 seconds. This speed was quite convenient for the educational process, ensuring the smooth implementation of the student assessment and tokenization processes [4][5].

DISCUSSION

Showed that adaptive learning models built on Web3 technologies have wide potential in the higher education system. It was found that platforms created using Web3 technologies have advantages over traditional online learning systems in terms of transparency, individual approach and motivation systems. The immutability of student activities and results using blockchain technology created a fair and reliable assessment system. This, in turn, increased student confidence and encouraged their active participation in the learning process [4].

Through the adaptive learning mechanism, educational materials were recommended that were appropriate for each student's individual knowledge level. Using a mathematical model, the dynamics of the knowledge level were determined, allowing students to identify their weaknesses and provide them with the necessary resources. This, in turn, significantly increased the effectiveness of education.

The tokenization system also played a significant role in increasing student motivation. Rewards in the form of tokens for each achievement encouraged students to be more active. At the same time, fairness and transparency were ensured because the tokens operated through a decentralized exchange system [6].

Some challenges were also identified during the research. In particular, the lack of the necessary technical infrastructure for working with Web3 technologies and the lack of user familiarity with these technologies may make it difficult to implement the system on a large scale. Also, problems such as transaction costs and delays of the blockchain network were highlighted. However, these challenges can be solved through technological solutions and optimization methods.

Based on the results obtained, the following recommendations can be made for the wider introduction of adaptive learning models based on Web3 technologies in the higher education system: first, universities need to modernize their infrastructure in accordance with blockchain technologies; second, special training on the basics of Web3 technologies should be organized for students and professors; third, it is advisable to conduct practical testing of the system's effectiveness by implementing pilot projects using Web3 technologies at the initial stage [7].

Overall, the research findings reveal that the combination of Web3 technologies and adaptive learning models has the potential to improve the quality of education, increase student motivation, and ensure transparency in the assessment system. In the future, there are prospects for further improvement of this model and its adaptation to other educational areas [8][9].

CONCLUSION

Showed that adaptive learning models created based on Web3 technologies are effective in the higher education system. Blockchain technology has the potential to enable immutable storage of assessment results, automatic assessment through smart contracts, and increased student motivation through a token system. Also, through an adaptive learning mechanism, learning materials are recommended that are tailored to the individual needs of each student. In the future, there are prospects for further improving this model and adapting it to other areas of education [8][10].

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