# Computer system for distance learning with integrated artificial intelligence

Dmytro V. Kostetskyi, Mariia Yu. Tiahunova and Halyna H. Kyrychek

*National University "Zaporizhzhia Polytechnic", 64 Zhukovskoho Str., Zaporizhzhia, 69063, Ukraine*

**Abstract**

In this paper, a distance learning system is developed to enhance the educational process and increase convenience for both teachers and students through the integration of artificial intelligence for test creation. This system introduces a unique and innovative functionality that enables the automatic generation of tests using AI, significantly reducing the time required by educators for test preparation. Before development, various modern tools were analyzed, and the Laravel framework, React library, and ChatGPT service were selected for their capabilities in building such a system. A monolithic architecture was chosen as it is best suited for this type of application, offering simplicity and ease of management. The development process included comprehensive testing, validation, and code optimization to minimize the system's footprint and improve the site's loading speed. An experiment involving AI-assisted test creation confirmed the system's effectiveness and efficiency, demonstrating a noticeable acceleration in the test generation process. The results indicate that the primary goal of the work—to develop a system that streamlines the educational process and reduces the burden on teachers—has been successfully achieved. This development not only contributes to the field of distance learning by offering a practical and time-saving tool but also showcases the potential of AI in educational technology, opening doors for further innovation in this domain.

**Keywords**

AI in education, artificial intelligence, automated test generation, distance learning, educational technology, distance learning, artificial intelligence, web

## 1. Introduction

In our unsettled times, when the world faces various military conflicts and epidemics, distance learning becomes the primary solution to educational challenges. It offers the opportunity to study safely from home or any secure location with internet access, bypassing physical attendance at educational institutions where it may be unsafe or where potentially ill individuals might be present. Due to rapid technological advancements and the proliferation of computers and phones, distance education is becoming increasingly relevant. Currently, one of the most well-known tools for this purpose is Moodle, an open-source learning management system available to anyone free of charge.

Distance learning has been evolving for decades, but it garnered significant attention during the COVID-19 pandemic when quarantine measures were implemented worldwide [1]. This accelerated the integration of distance learning into traditional face-to-face education systems. The flexibility of distance learning allowed educational programs to continue nearly on schedule, customized to individual study plans. However, despite its advantages, distance learning also has negative impacts on health, such as worsening eyesight, posture issues, and psychological aspects.

Distance learning offers many advantages over traditional classroom attendance. Students can study materials anywhere and review them as needed. Lectures and assignments can be downloaded for offline study, eliminating the need for constant access to light or internet. Economically, distance learning

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dimakost1111@gmail.com (D. V. Kostetskyi); mary.tyagunova@gmail.com (M. Yu. Tiahunova); kirgal08@gmail.com (H. H. Kyrychek)

https://csn.zntu.edu.ua/tyagunova-maria-uriivna (M. Yu. Tiahunova); http://csn.zntu.edu.ua/galina-grigorivna-kirichek (H. H. Kyrychek)

0009-0001-7020-942X (D. V. Kostetskyi); 0000-0002-9166-5897 (M. Yu. Tiahunova); 0000-0002-0405-7122 (H. H. Kyrychek)

is more cost-effective than traditional methods, reducing expenses on travel, accommodation, and heating in dormitories and institutions. Many distance learning programs are also more affordable than traditional education. However, drawbacks include reduced social interaction for students and potential health issues from prolonged screen time, although eye specialists recommend specific exercises to mitigate these effects.

The aim of this work is to enhance the educational process and improve its convenience for both teachers and students by developing a distance learning system capable of generating tests using artificial intelligence.

Having analyzed the subject area of distance learning systems and explored their functionality, several key conclusions have been drawn. First and foremost, the system should employ cutting-edge technologies that promote the development of a new type of education, specifically distance education, providing seamless access to educational materials from any device with internet connectivity. Examining how distance education is conducted revealed advantages such as schedule flexibility and accessibility of learning, but there are drawbacks in terms of limited "live" interaction between students and teachers.

The system's terminology, roles, and processes occurring within the distance learning environment have been defined and clearly delineated between the capabilities of teachers and students.

By analyzing the requirements for the software product, the key functionality and system features have been determined. Requirements for users with different roles have been considered, defining basic functionality, the need for an adaptive interface, product optimization, data security, and future expansion capabilities.

In evaluating the available tools for system development, particular attention was given to the following criteria: project specificity, programming language, security, and experience. As a result of this process, the following technologies were chosen: the Laravel framework for backend and the React library for frontend [3]. These tools have great potential for efficient project development and will contribute to the system's further advancement, thanks to their advantages and support. Services

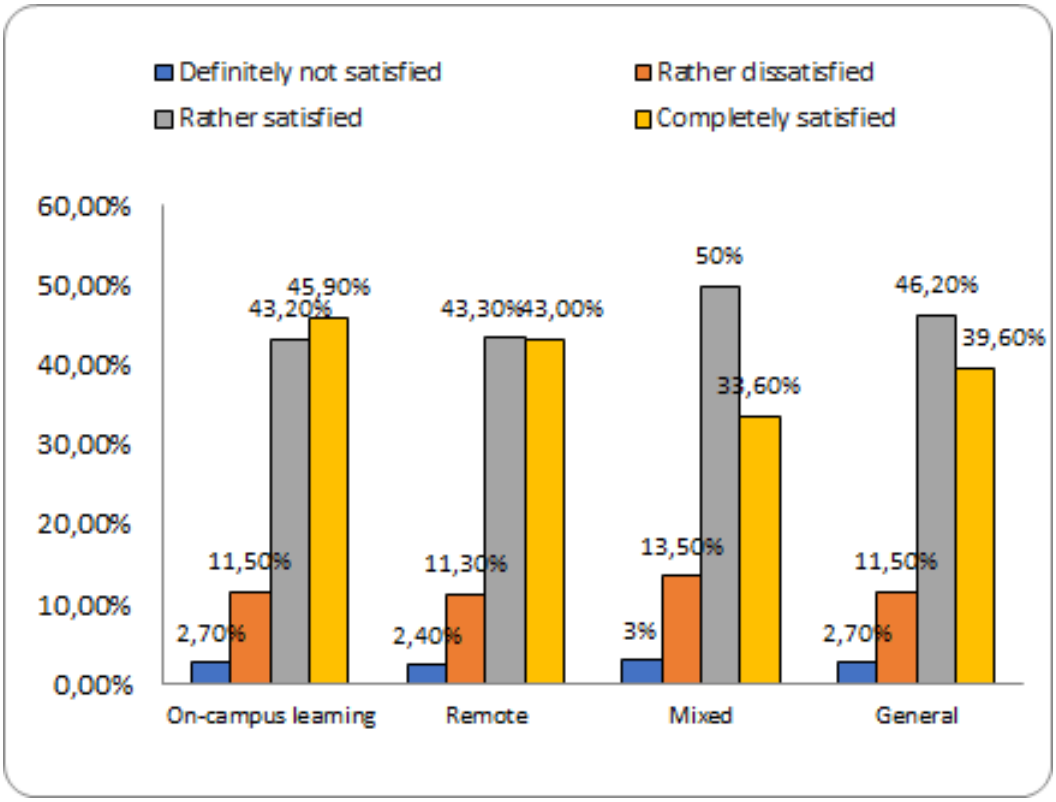


**Figure 1:** Satisfaction level of employees and students in distance education in 2022 [2].

providing convenient APIs were also reviewed, facilitating interaction with artificial intelligence by simply sending specific commands.

Conducting a detailed analysis of the impact of distance education over the years, it became evident that this is a promising direction, as in recent years it has proven to be a good alternative to physical attendance at classes. In connection with this, Ukraine has a special state service tasked with evaluating the quality of education, established since 2017. Given the active development of distance education over the past three years, during this time, the service has conducted a significant number of surveys and studies. Surveys are anonymous and conducted via online forms designed for participants in the educational process from various parts of the country. These surveys analyze the gathered information and provide suggestions for improving the educational process.

Figure 1 illustrates the survey results for the 2022-2023 academic year. Participation in the survey involved 7,319 respondents (71% female and 29% male), including 5,635 higher education students and 1,684 educational and scientific-pedagogical staff.

Most participants who took part in the survey have been in Ukraine since the beginning of the war – 74.4% of students and 83.4% of teachers. Participants residing abroad include 8.6% of education seekers and 4.8% of educational and scientific-pedagogical staff [2].

Such surveys have been conducted before, due to the beginning of quarantine and the transfer of all educational institutions from the usual full-time to full-fledged distance learning, which was stressful for everyone involved in the educational process. In April 2021, after the end of the first full academic year, conducted in a mixed form, a survey was conducted among representatives of the administration, staff and students for the 2020-2021 academic year, a total of 9184 people. The topic of the survey was to assess the level of organization of the distance format using a scale from 1 to 5. The results are shown in figure 2. It can be seen that, on average, distance learning has no negative impact on the level of education.

In May 2022, a new survey was conducted in higher education institutions, and 27 thousand questionnaires were received based on the results of the 2021-2022 academic year, which assessed the quality of distance learning and martial law, figure 3 shows the result [5]. Analyzing it, we can understand that

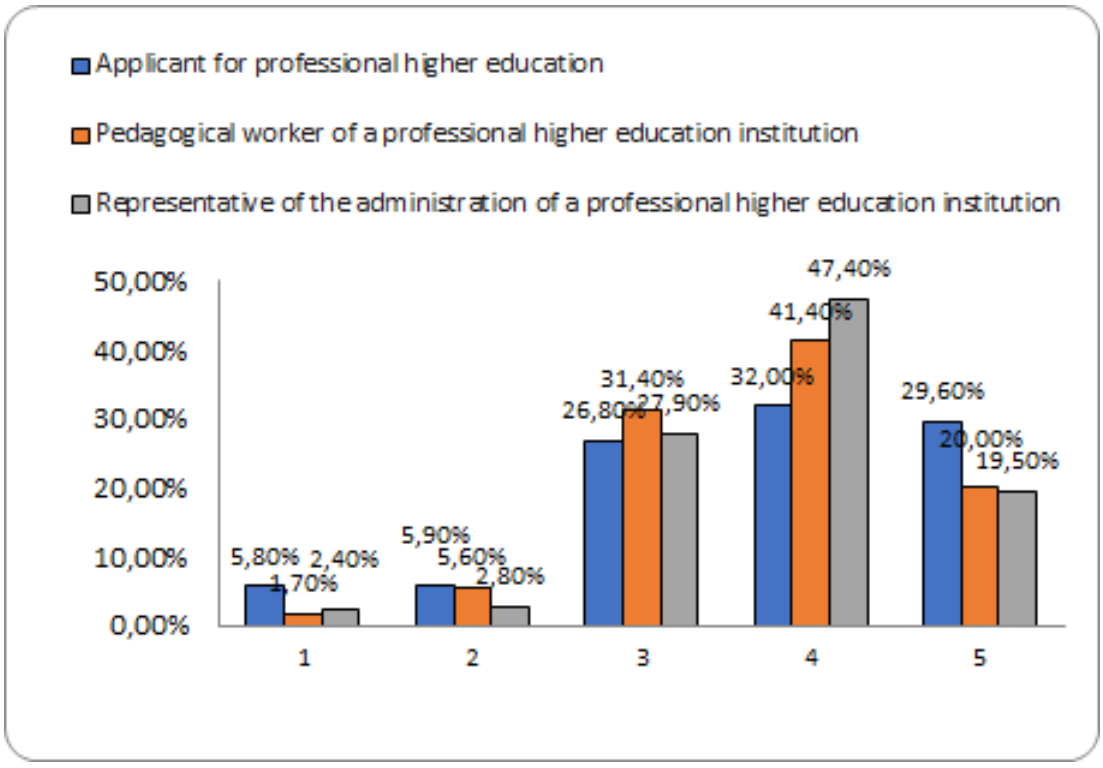


**Figure 2:** Assessment by respondents of the outcomes of the 2020-2021 academic year [4].

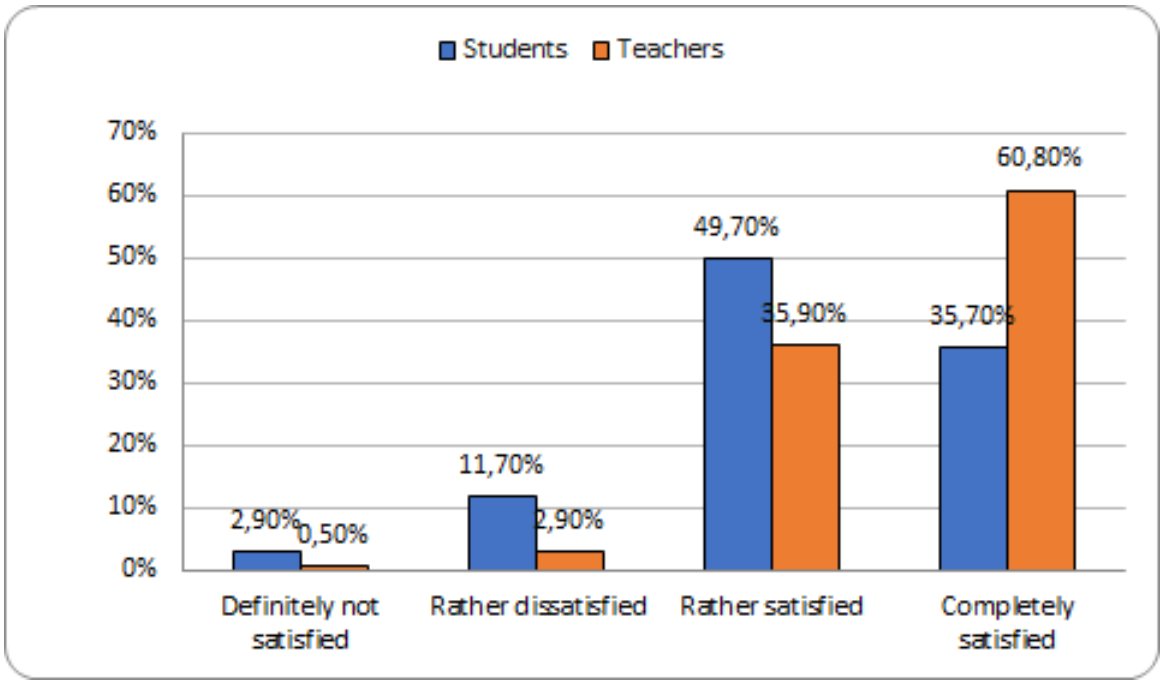


**Figure 3:** Satisfaction level of employees and students in distance learning in 2022 [5].

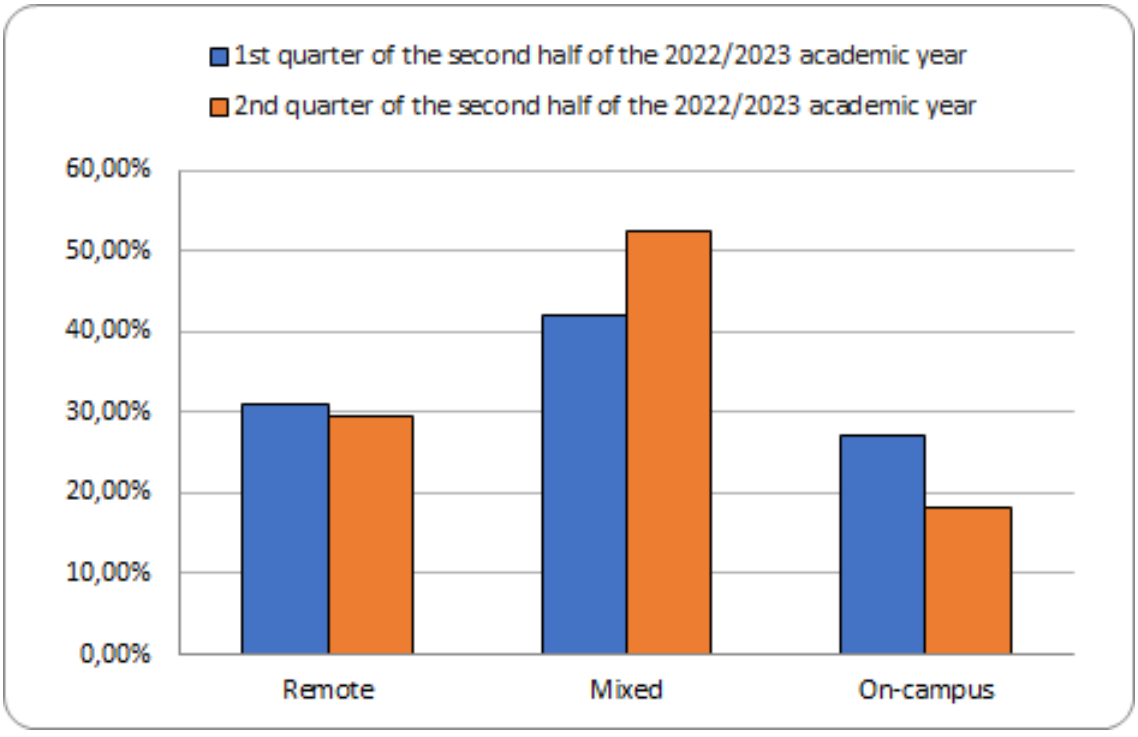


**Figure 4:** Schedule of changes in training formats in 2022-2023 [6].

the vast majority of respondents are satisfied with their studies, even in such a difficult time for the country. All this was achieved because educational institutions already had experience with distance learning and it was not an additional stress for people.

In 2023, a large number of different surveys were conducted with 40 thousand people participating. Among them, the main ones were about: learning formats, assessment of learning forms, and assessment of knowledge compared to 2022.

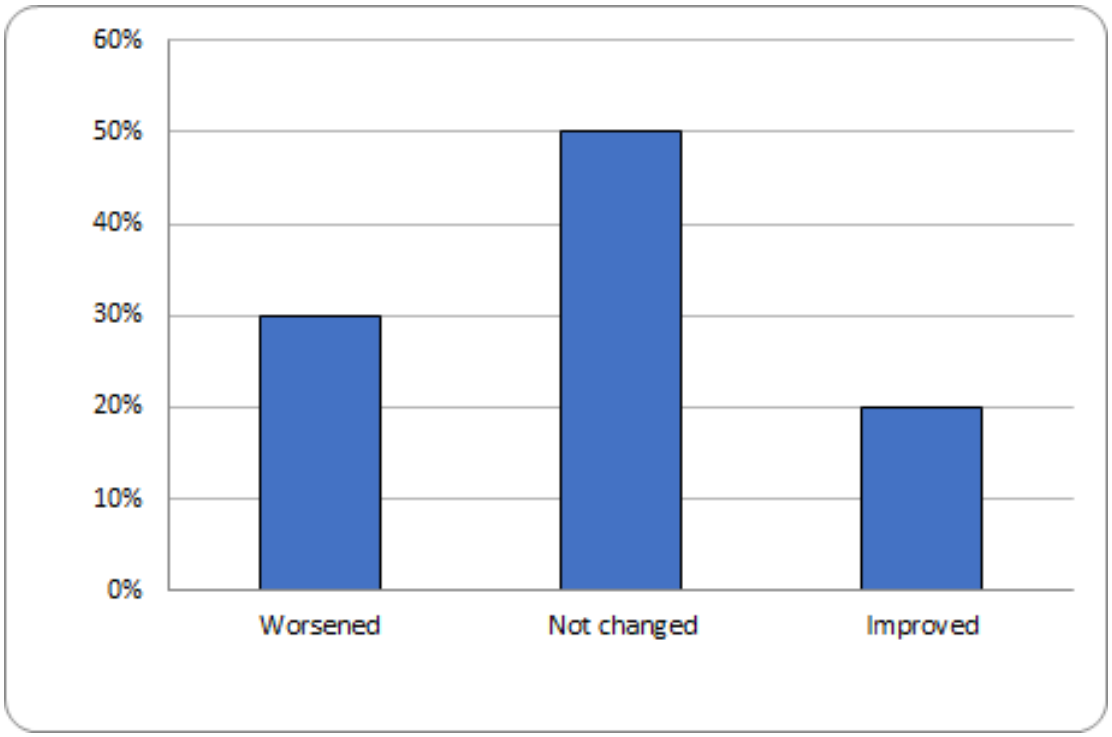


**Figure 5:** How the results changed in the second half of 2022/2023 compared to the previous academic year [6].

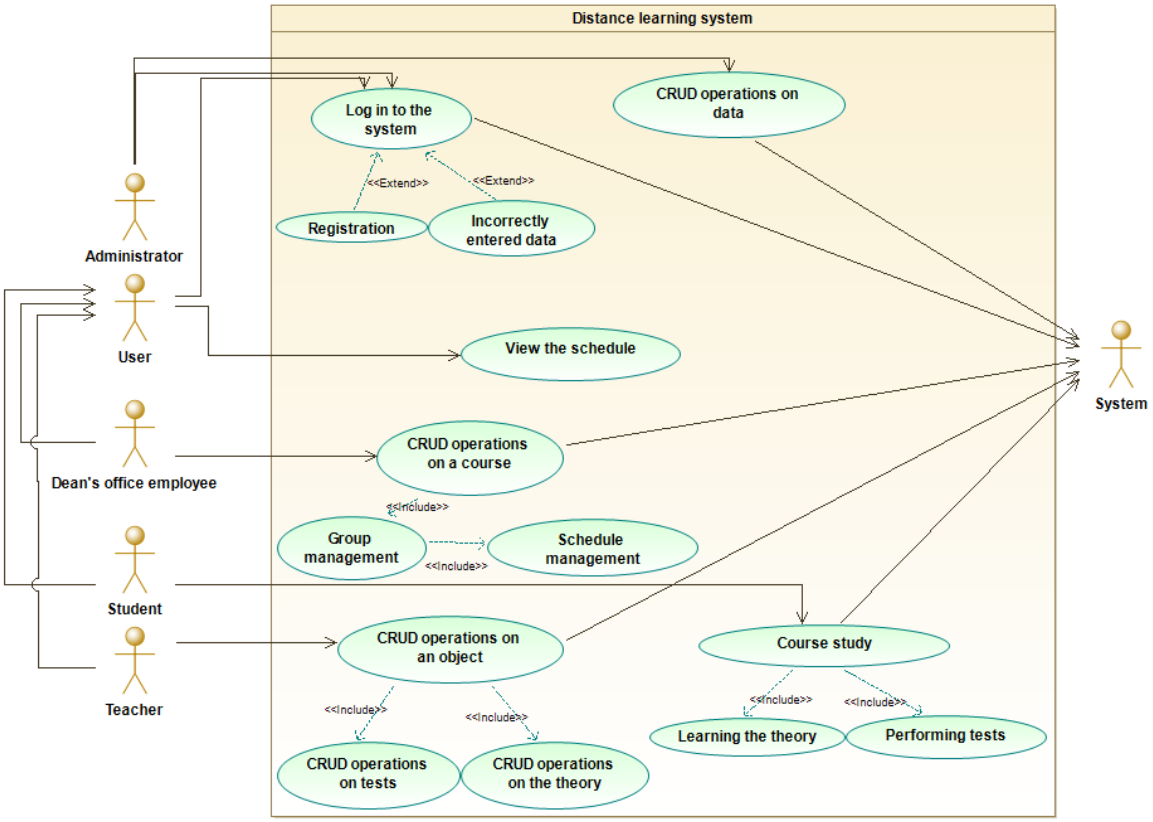


**Figure 6:** Use Case diagram of the distance learning system.

So, first, let's look at how the forms of education have changed throughout Ukraine. Figure 4 shows that due to the fact that the situation in the country has relatively stabilized in the second quarter

compared to the first, but as we can see, educational institutions prefer a mixed format because it is relatively safe due to the state of emergency in the country, and therefore the share of full-time education is decreasing.

Next, a survey was conducted among teachers to compare the level of knowledge of students in the second half of 2022-2023 with the previous year. Figure 5 shows that 30% of teachers said that the level of knowledge had deteriorated, and 20% said it had improved. However, it can be pointed out that the decline may be due to the fact that students have a lot of factors that impede their studies, including: alarms during which most institutions stop working, and the fact that they have to stay in shelter at this time, power outages, and attacks on important infrastructure by Russia. Therefore, experts say that despite all the difficulties, the institutions are functioning and providing knowledge in a relatively stable manner.

## 2. Results

During the design process, we identified and described what users should see, their functions, division into roles, server performance, and its ability to back up information at a certain frequency.

Modeling allowed us to determine the interaction of components and optimize their performance. The use of option diagrams and sequence diagrams provided a detailed overview of the functionality and user interactions with the system. The sequence diagram visualized the processes and interactions between the system components. This helped to optimize the sequence of events and clarify the relationships between elements, which will help in the development of the system. For example, figure 6 shows the system under development at the conceptual level, with the help of a diagram using a special modeling language – UML, because this language is standardized, and the scheme described according to the rules will be understood by everyone who works with it.

When choosing a server architecture, we chose a monolithic one because it can provide efficiency, scalability, and ease of system development. Figure 7 shows the interaction of the system blocks.

The user interface was designed and sketches were created, which will be used to develop the client side. The key aspects of the user experience and appearance of the system have been identified to ensure ease of use and minimalist design. For example, the layout of the main page is shown in figure 8.

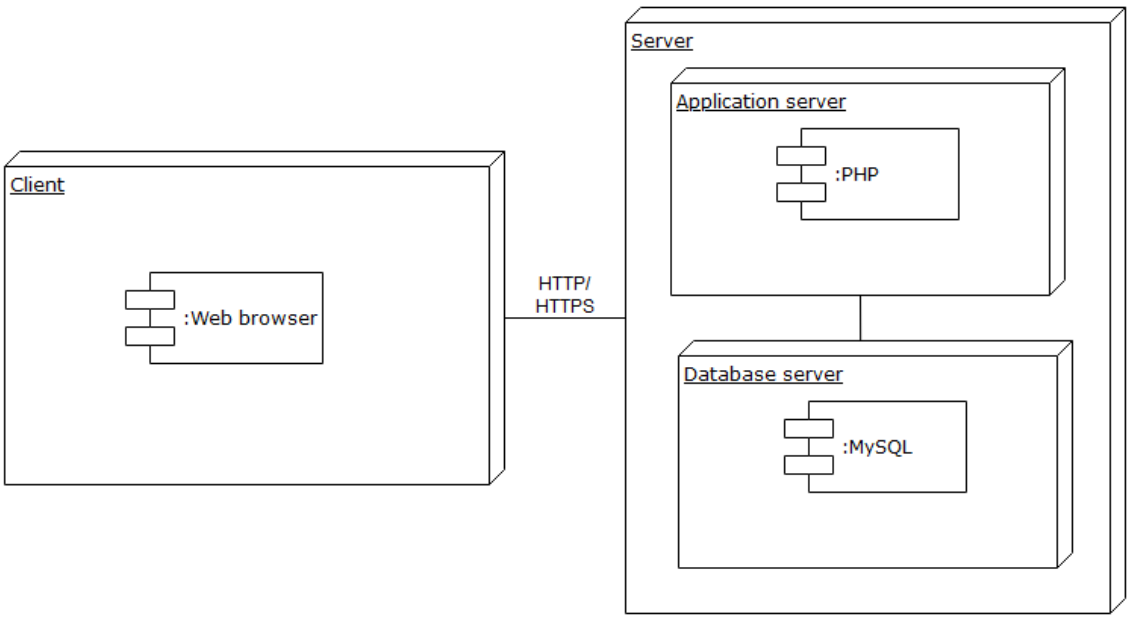


**Figure 7:** Deployment diagram.

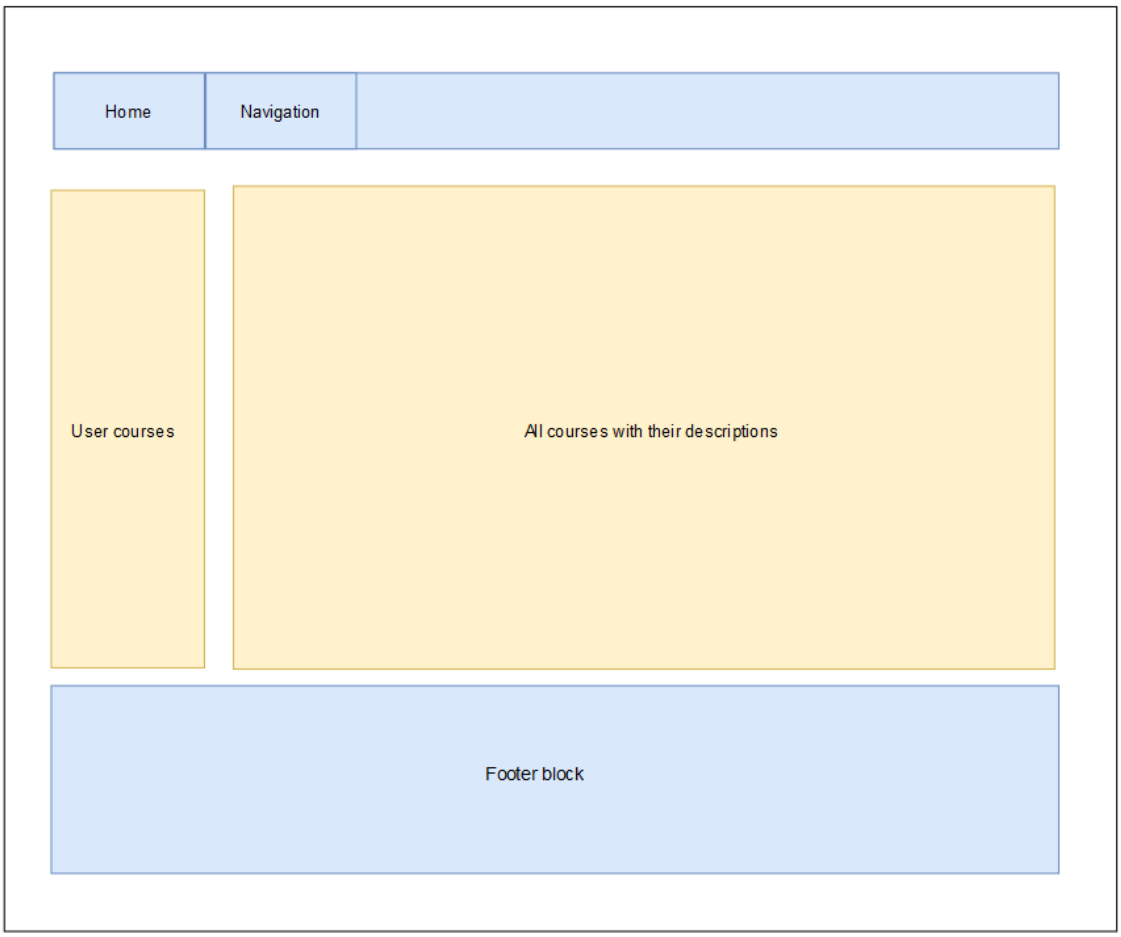


**Figure 8:** Home page design.

To create the backend, we first looked at setting up a development environment using Open Server on Windows, then described the main points of creating a project and its initial configuration. Next, we described the most important code blocks and added an explanation of how it works, considering how the backend sends requests to the AI service using asynchronous queues and automatically creates tests from the received response.

The next step was to add the frontend to an existing project using special commands and a package manager that automatically configures all dependencies and installs auxiliary libraries. We describe the methods by which information is exchanged between the client and the server, how headers are generated, how to validate the data entered into the forms, and how the components are displayed. Figure 9 shows the implemented main page that interacts with the backend.

The figure 10 shows how the course is displayed when you go to it. Lecture materials, links to literature, or just information are displayed in blue, and tests are displayed in green.

Figure 11 shows how to create a test and add questions to it (figure 12). The first step is to open the course and click on the “Add test” button, where you will be prompted to enter the following data: name, description, and number of questions. After that, you need to choose the type of question filling, there are two options: generate with the help of AI, or click the “Create” button and fill in the questions manually. When you choose to generate questions by artificial intelligence, a request is made to the ChatGPT service, which returns an answer, from which questions for testing are automatically created. After successful addition, the teacher can review the created test by viewing: the topic, description, and added questions with marked correct answers.

Figure 13 shows how a student takes a test. The student goes to the course page, where he or she

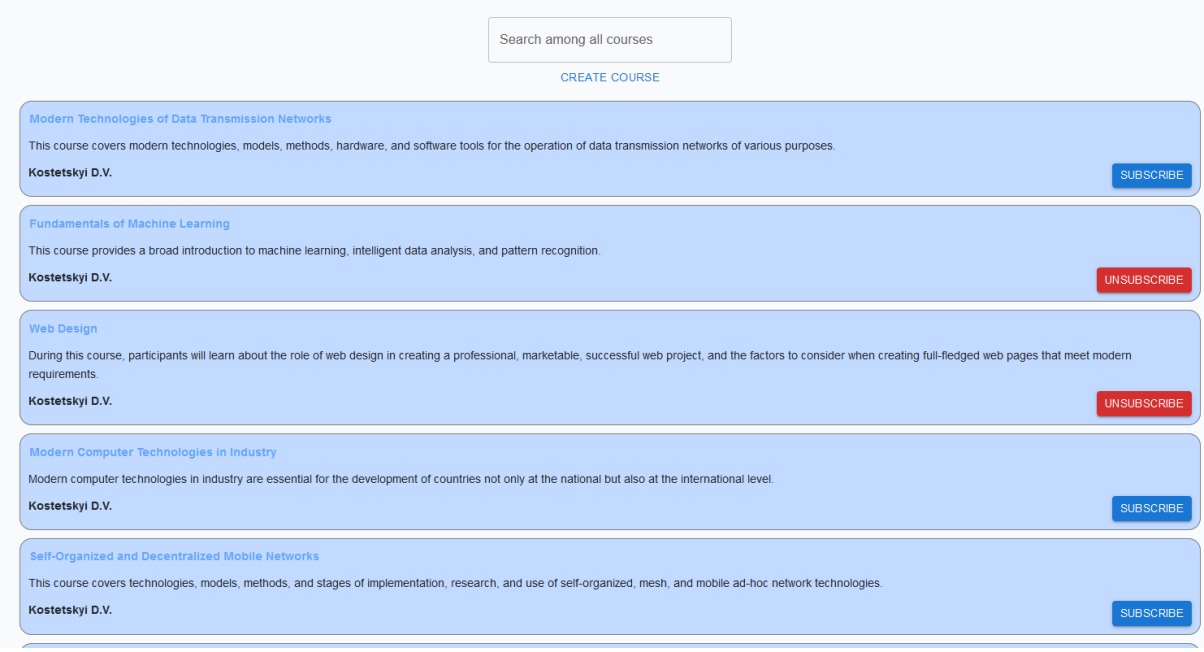


**Figure 9:** Implemented main page that interacts with the backend.

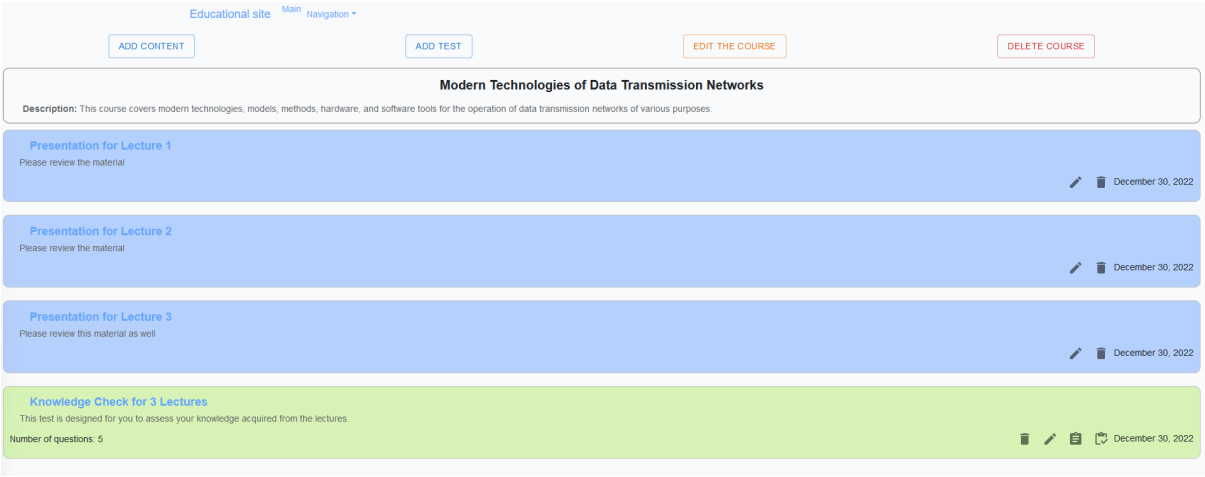


**Figure 10:** View of the course.

selects a particular test, and then a page opens with questions that are randomly selected from all the previously added questions and the number of questions that the instructor has set, in our case 5. The figure shows that you need to answer 5 random questions, although 8 were created in the test itself. After passing the test, the student is shown the number of correct answers and redirected to the main page of the course.

Figure 14 shows the tables that were created on the server to store the data received from users.

Another important stage is the process of validation, compilation and compression of the code, after which we received a fully tested code that can break only in case of a logic error, not a syntax error, and it was also compressed, which gives an increase in the speed of opening the site, as its weight has decreased.

During the functional testing of the system, we checked its protection against possible abnormal connection, the operation of form validation, main functionalities and the detection of possible errors. This allowed us to ensure the high quality of the system and its compliance with the defined requirements.

Creating tests is an important part of the educational process, but it can be a time-consuming

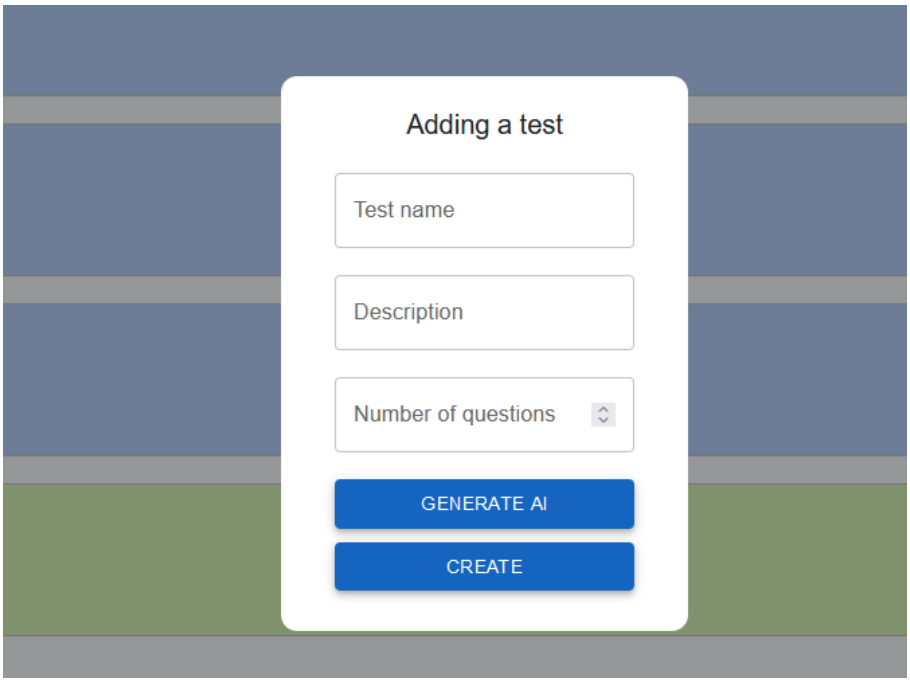


**Figure 11:** Adding a test.

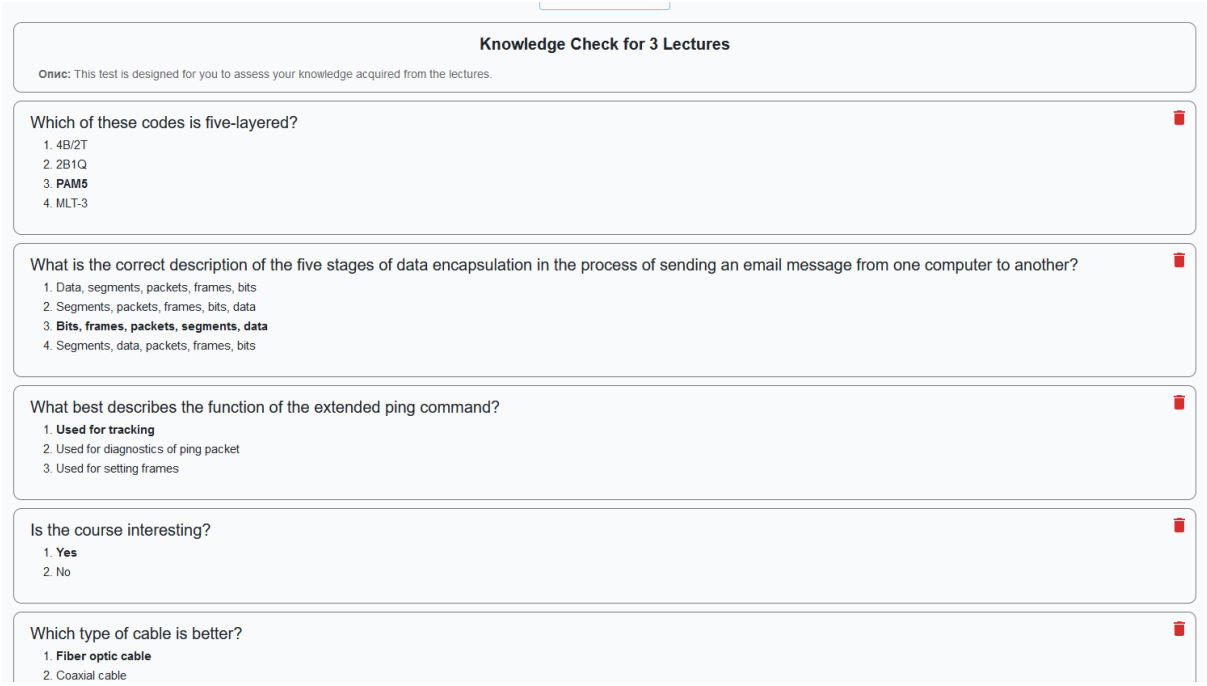


**Figure 12:** Adding questions.

and tedious task for a teacher. Compared to manually creating tests, using artificial intelligence to automatically generate tests can save a lot of time. The teacher only needs to specify the test parameters, and AI will automatically create the test in seconds. This approach can make routine work easier, increase his or her productivity, and allow more attention to other aspects of the learning process. If we compare these two approaches, we can understand that with automatic generation, the teacher's time consumption is reduced, and fatigue does not appear, which has a good effect on his or her productivity. Thus, both teachers and AI have their own advantages and limitations in creating tests.

To more accurately assess the performance and efficiency of the automated test generation system,

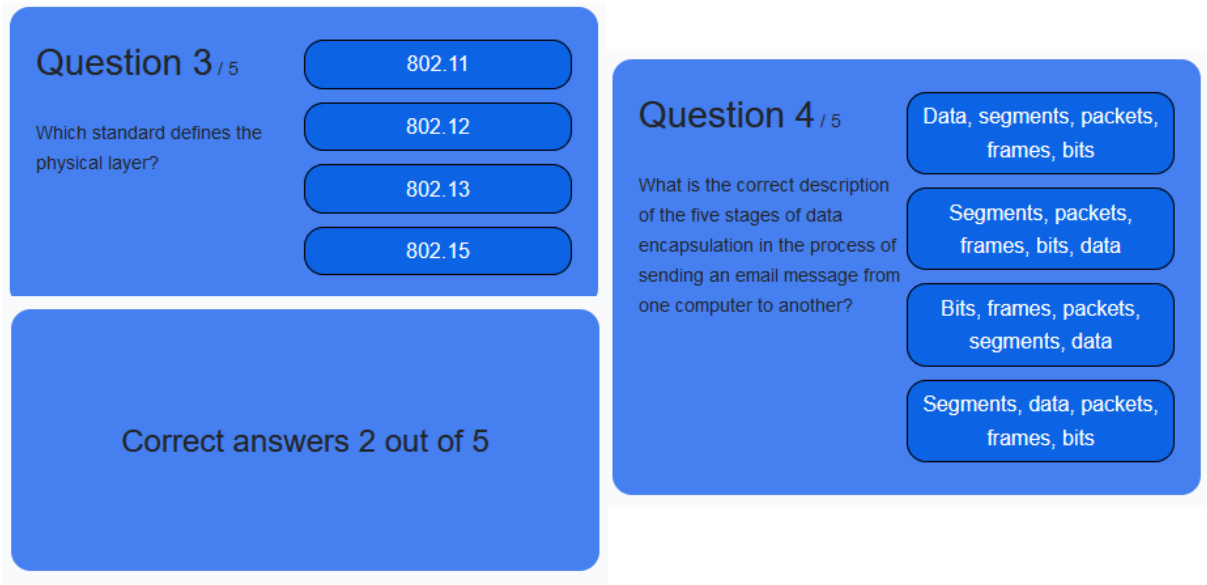


**Figure 13:** Test for students.

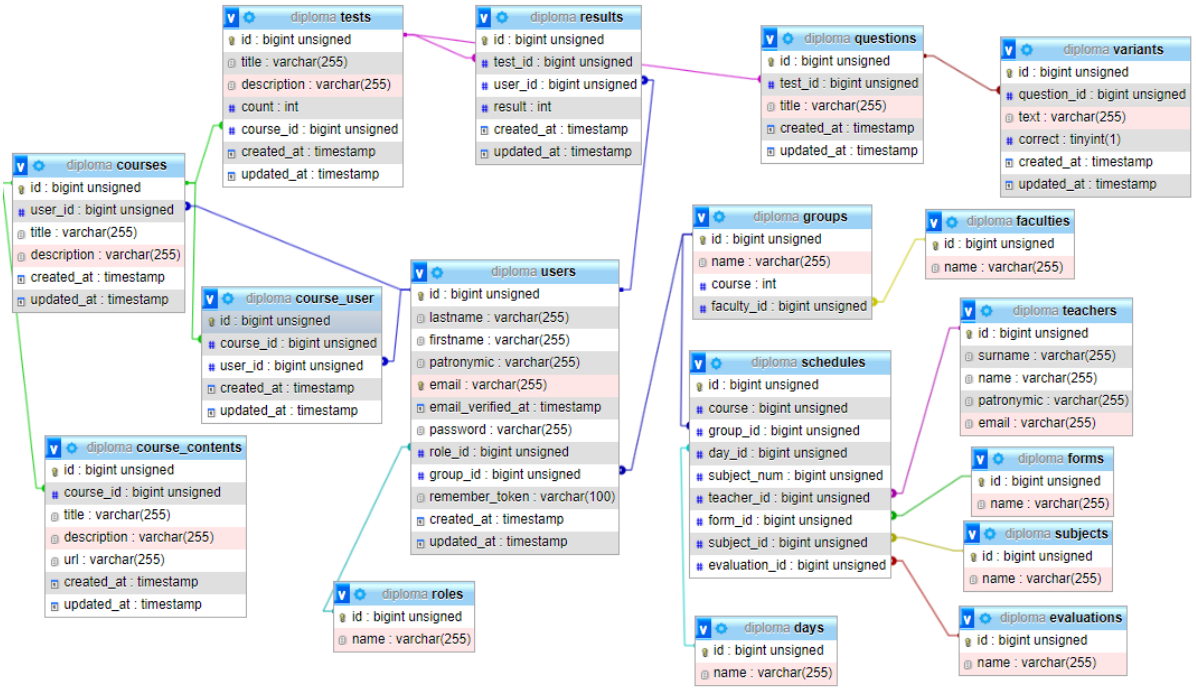


**Figure 14:** The tables that were created on the server to store the data received from users.

multiple tests were conducted involving a teacher. These tests simulated various scenarios in which tests of different complexities were created. The goal was to gain insight into how the system operates under different conditions to obtain the most accurate results possible.

Multiple test runs and averaging process, the teacher was tasked with creating several tests manually and using the AI-based system. These tests covered various levels of complexity, ranging from simple to more challenging questions.

For each test, the time spent by the teacher was recorded. In the manual process, the time required to create each question and the total time needed to compile a complete test of 25 questions were taken into account. Simultaneously, the time the AI system took to generate the test and the additional time the teacher spent checking and correcting the generated test were measured.

To ensure accurate results, each testing scenario was repeated several times. This approach allowed for capturing variations in the time required to complete the tasks. The results of all test runs were

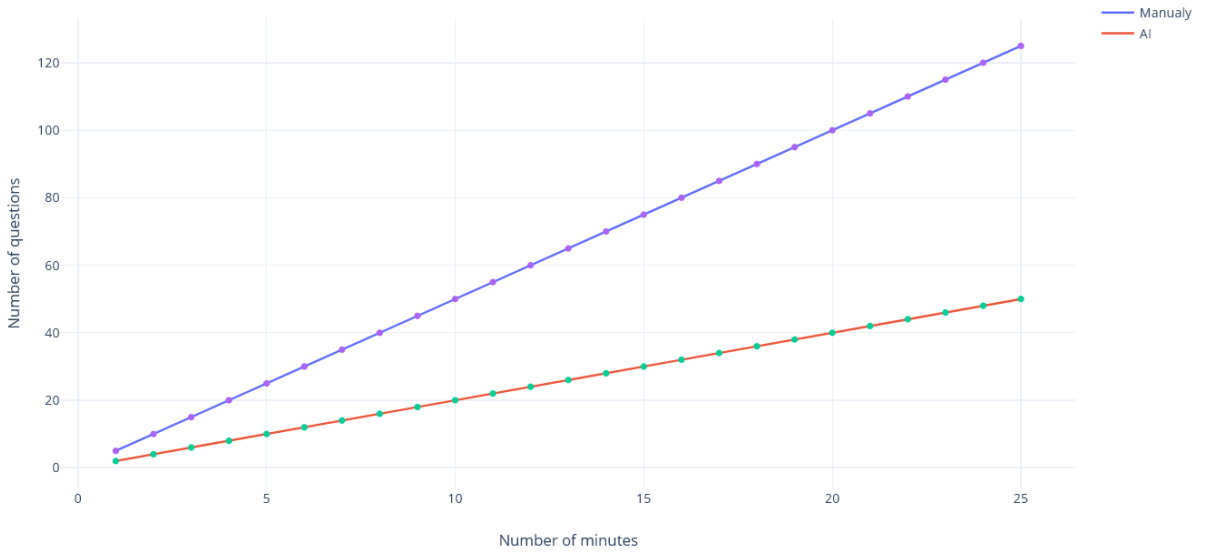


**Figure 15:** Time dependence on the number of questions.

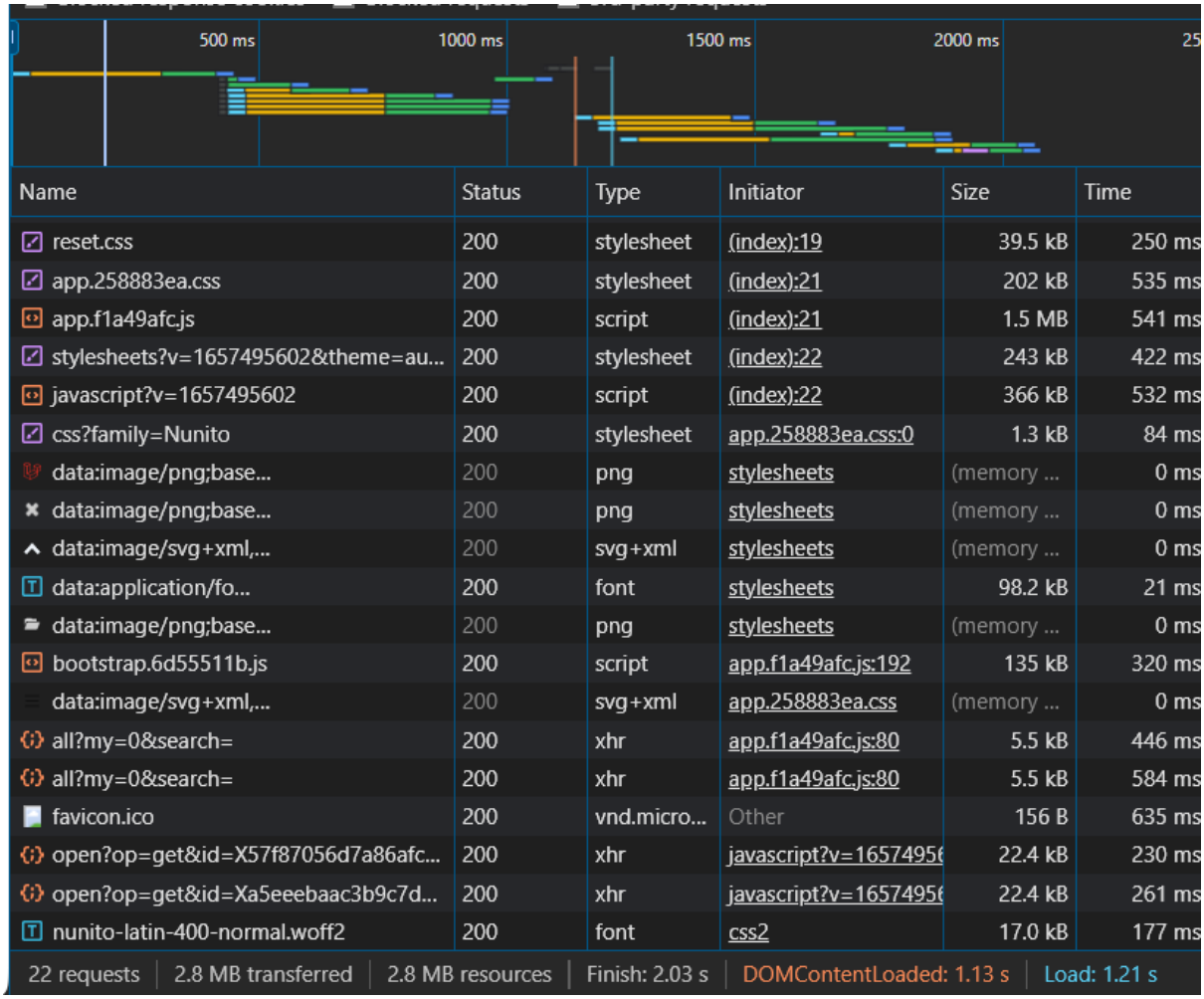


**Figure 16:** Information about the main page of the developed system.

averaged to obtain data on the time spent on both manual and automated test creation. These averaged results provide a more precise view of the time required than a single test, where any anomalies or outliers that might have occurred during one test run could have affected the final result. Additionally, a delay was introduced between the creation of the tests during the experiment to eliminate the factor of teacher fatigue.

The time a teacher spends on creating a test manually depends on the complexity of the test. Figure 15 shows on average, it was observed that creating one question took about 5 minutes. For a standard test consisting of 25 questions, about 125 minutes were required. When using the AI system, the time required for generating the test and making necessary corrections was significantly reduced. On average, the teacher spent about 1 minutes checking and correcting the generated test. In total, it took only about 23 minutes to generate tests and check the answers to 25 questions. The results show the great potential of this innovation for practical use [7].

The practical testing of the functionality showed that the system created tests with perfect quality and no corrections to the answer options.

After analyzing existing analogues on the Internet, one of the most popular ones, Moodle [8, 9, 10], was chosen for comparison with the developed system [11]. In the comparison, we analyzed how much Internet traffic they consume when navigating between pages.

When the developed system is opened for the first time, the entire client-side part is loaded, as shown in figure 16, with the main page size 2.8 MB.

Let's consider how quickly the competitive system Moodle loads. In figure 17, it is shown that when loading the main page, it occupies 2 MB, which is almost the same as the developed system.

| | | | | | |
|---|---|---|---|---|---|
| yui_combo.php?3.18.1/event-mousew... | 200 | script | yui_combo.php?rollup | 5.7 kB | 70 ms |
| f2?rev=166811 | 200 | png | courses.php:172 | 2.5 kB | 66 ms |
| pdf | 200 | svg+xml | courses.php:549 | 1.9 kB | 67 ms |
| service-nologin.php?info=core_output... | 200 | xhr | jquery-3.7.1.min.js:2 | 1.7 kB | 68 ms |
| monologo | 200 | svg+xml | courses.php:549 | 1.5 kB | 66 ms |
| yui_combo.php?rollup/3.18.1/yui-moo... | 200 | stylesheet | courses.php:12 | 1.4 kB | 70 ms |
| monologo | 200 | svg+xml | courses.php:549 | 1.2 kB | 64 ms |
| idea.min.css | 200 | stylesheet | courses.php:13 | 1.1 kB | 68 ms |
| monologo | 200 | svg+xml | courses.php:549 | 1.1 kB | 65 ms |
| monologo | 200 | svg+xml | courses.php:549 | 1.0 kB | 68 ms |
| monologo | 200 | svg+xml | courses.php:549 | 992 B | 66 ms |
| grademe.js | 200 | script | courses.php:2088 | 705 B | 64 ms |
| mobile.webmanifest.php | 200 | manifest | Other | 679 B | 68 ms |
| styles.php | 200 | stylesheet | courses.php:14 | 235 B | 69 ms |
| collect?v=1&_v=j101&aip=1&a=1702... | 200 | gif | analytics.js:22 | 55 B | 28 ms |
| collect?v=1&_v=j101&aip=1&a=1702... | 200 | xhr | analytics.js:36 | 35 B | 46 ms |
| collect?v=2&tid=G-ZK66K7Z217&gtm... | 204 | fetch | js?id=G-ZK66K7Z217 | 17 B | 48 ms |
| data:image/svg+xml;... | 200 | svg+xml | Other | (memory ... | 0 ms |
| data:image/svg+xml;... | 200 | svg+xml | Other | (memory ... | 0 ms |
| 38 requests \| 1.9 MB transferred \| 7.3 MB resources \| Finish: 6.85 s \| DOMContentLoaded: 680 ms \| Load: 1.83 s | | | | | |

**Figure 17:** The size of the Moodle home page.

The size of the site is influenced by many factors, but the main one is that the Moodle system uses server-side rendering. That is, it receives a complete representation of the page from the backend, which is quite resource-intensive since a large amount of various auxiliary HTML tags are transmitted. And the same thing happens every time a new page is opened. With a poor internet connection, such a site will load very slowly or may not load at all. At the same time, the developed system uses a

connection in which asynchronous requests are sent in JSON format, and therefore do not contain unnecessary information. As a result, such a system consumes less memory because it does not reload pages from scratch with each transition, as they were all loaded during the first visit to the site. For a more illustrative example, five transitions between different pages were made in these two systems, the

| | | | | | |
|---|---|---|---|---|---|
| 22 requests | 2.8 MB transferred | 2.8 MB resources | Finish: 2.03 s | DOMContentLoaded: 1.13 s | Load: 1.21 s |
| 31 requests | 2.9 MB transferred | 2.9 MB resources | Finish: 2.2 min | DOMContentLoaded: 1.13 s | Load: 1.21 s |
| 47 requests | 3.0 MB transferred | 3.0 MB resources | Finish: 2.9 min | DOMContentLoaded: 1.13 s | Load: 1.21 s |
| 56 requests | 3.1 MB transferred | 3.1 MB resources | Finish: 3.3 min | DOMContentLoaded: 1.13 s | Load: 1.21 s |
| 61 requests | 3.2 MB transferred | 3.2 MB resources | Finish: 3.6 min | DOMContentLoaded: 1.13 s | Load: 1.21 s |

**Figure 18:** Five queries in the developed system.

| | | | | | |
|---|---|---|---|---|---|
| 48 requests | 2.0 MB transferred | 7.5 MB resources | Finish: 7.40 s | DOMContentLoaded: 1.16 s | Load: 2.40 |
| 60 requests | 2.2 MB transferred | 7.9 MB resources | Finish: 1.1 min | DOMContentLoaded: 1.16 s | Load: 2. |
| 33 requests | 1.8 MB transferred | 6.9 MB resources | Finish: 7.65 s | DOMContentLoaded: 1.33 s | Load: 2.39 |
| 31 requests | 1.8 MB transferred | 6.9 MB resources | Finish: 2.05 s | DOMContentLoaded: 645 ms | Load: 1.4 |
| 37 requests | 1.9 MB transferred | 7.3 MB resources | Finish: 3.08 s | DOMContentLoaded: 918 ms | Load: 2.7 |

**Figure 19:** Five queries in the Moodle site.

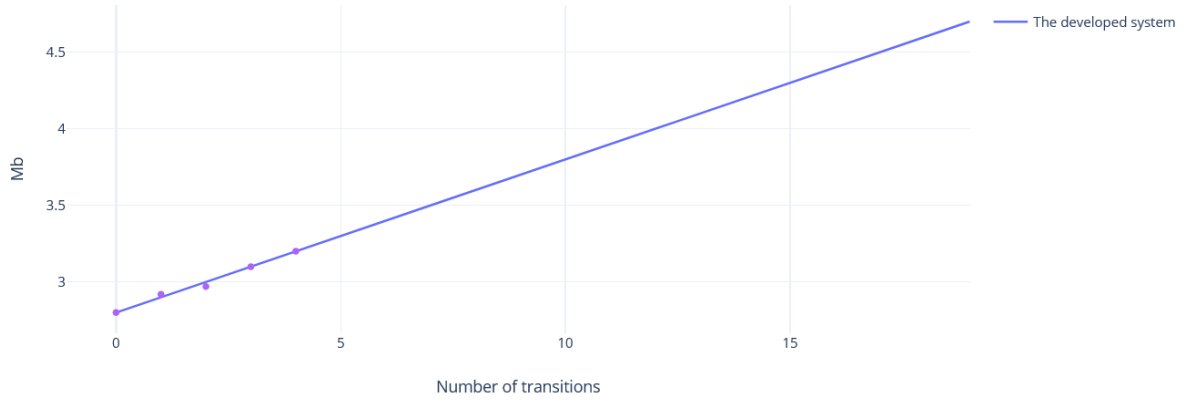


**Figure 20:** The traffic consumed by the developed system.

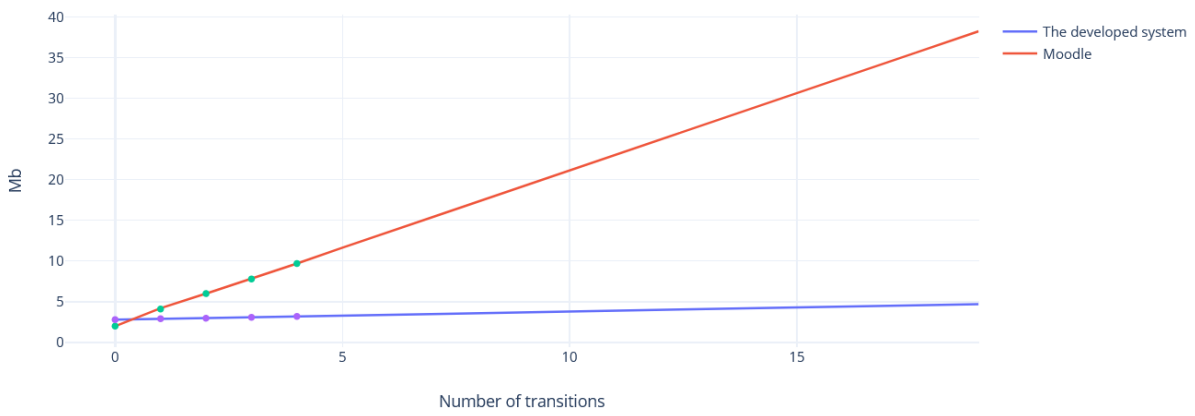


**Figure 21:** Comparison of traffic size.

result is shown in figure 18 and figure 19.

From the figures, it is clear that since the developed system exchanges information with the backend through AJAX, the site loads only once, and during transitions, requests are simply sent that add weight to the initial load. In contrast, Moodle uses server-side rendering, and with each page transition, requests are repeated and new information is added. In figure 20, the graph of the approximate traffic consumed by the developed system is shown, and in figure 21, a comparison of both systems is presented to highlight the difference.

In this comparison, only queries were weighted, as these measurements could be affected by images on the site, so they were excluded for accuracy. It can be concluded that the developed system is more optimized for users with poor internet connection than Moodle.

The site was also optimized with the help of semantic kernel and keyword generation to increase the ranking and relevance to search queries. The use of a semantic core also facilitated the creation of an effective and user-friendly resource. The last step was to promote the system on the Internet, ensuring that the site was indexed through sitemap.xml and robots.txt, as well as checking the performance through Google Console to ensure stability and visibility on the web.

## 3. Conclusion

The results obtained in this paper are a solution to the practical problem of increasing the efficiency of test creation using artificial intelligence.

Thus, a distance learning system was developed to improve the educational process and enhance the convenience of conducting the educational process for teachers and students by integrating artificial intelligence into the system for creating tests.

The system allows for the creation of tests using artificial intelligence, significantly reducing the time required by teachers. It enables the creation of tests of various difficulty levels, which helps to identify weak areas in students' knowledge and adjust the educational process more effectively.

The framework Laravel, the React library, and the ChatGPT service were chosen for the development to utilize artificial intelligence. The chosen monolithic architecture is the best fit for a system of this type. After development, comprehensive testing, validation, and code minimization were performed, improving the site's load speed and efficiency. An experiment with creating a test using AI confirmed the speed and effectiveness of the system.

## References

[1] S. O. Semerikov, T. A. Vakaliuk, I. S. Mintii, V. A. Hamaniuk, V. N. Soloviev, O. V. Bondarenko, P. P. Nechypurenko, S. V. Shokaliuk, N. V. Moiseienko, V. R. Ruban, Mask and Emotion: Computer Vision in the Age of COVID-19, in: Digital Humanities Workshop, DHW 2021, Association for Computing Machinery, New York, NY, USA, 2022, p. 103–124. doi:10.1145/3526242.3526263.

[2] The State Service of Education Quality of Ukraine, Informatinal and analytical reference regarding the organization of the educational process in institutions of vocational pre-university and higher education of ukraine under martial law, 2023. URL: https://sqe.gov.ua/wp-content/uploads/2023/08/IAD_II_kvartal_FPO_ZVO_SQE-2023.pdf.

[3] S. Anam, A. Sifaunajah, Design and Build a Web-based Learning Management System Using the Laravel Framework, Prosiding SEMNAS INOTEK (Seminar Nasional Inovasi Teknologi) 6 (2022) 013–018. doi:10.29407/inotek.v6i1.2444.

[4] The State Service of Education Quality of Ukraine, Analytical reference regarding trends in the organization of distance education in institutions of vocational pre-university and higher education under quarantine conditions in the 2020/2021 academic year, 2021. URL: https://sqe.gov.ua/wp-content/uploads/2021/05/ANALITICHNA_DOVIDKA_Opituvannya_FPO_ZVO_DSYAO_05.2021.pdf.

[5] The State Service of Education Quality of Ukraine, Analytical reference regarding trends in the organization of distance learning in institutions of higher education in the 2021/2022 academic year under martial law, 2023. URL: https://sqe.gov.ua/wp-content/uploads/2023/01/ANALITICHNA-DOVIDKA-ZVO_12.06.pdf.

[6] The State Service of Education Quality of Ukraine, Analytical reference regarding the organization of the educational process in institutions of vocational pre-university and higher education of ukraine under martial law, 2023. URL: https://sqe.gov.ua/wp-content/uploads/2023/08/IAD_II_kvartal_FPO_ZVO_SQE-2023.pdf.

[7] M. Y. Tiahunova, H. H. Kyrychek, D. V. Kostetskyi, Time savings calculation in test creation using Artificial Intelligence, Systems and Technologies 67 (2024) 65–71. doi:10.32782/2521-6643-2024-1-67.10.

[8] H. Athaya, R. D. A. Nadir, D. Indra Sensuse, K. Kautsarina, R. R. Suryono, Moodle Implementation for E-Learning: A Systematic Review, in: Proceedings of the 6th International Conference on Sustainable Information Engineering and Technology, SIET '21, Association for Computing Machinery, New York, NY, USA, 2021, p. 106–112. doi:10.1145/3479645.3479646.

[9] M. J. Nácher, L. Badenes-Ribera, C. Torrijos, M. A. Ballesteros, E. Cebadera, The effectiveness of the GoKoan e-learning platform in improving university students' academic performance, Studies in Educational Evaluation 70 (2021) 101026. doi:10.1016/j.stueduc.2021.101026.

[10] M. Ouadoud, N. Rida, T. Chafiq, Overview of E-learning Platforms for Teaching and Learning, International Journal of Recent Contributions from Engineering, Science & IT (iJES) 9 (2021) pp. 50–70. doi:10.3991/ijes.v9i1.21111.

[11] N. H. S. Simanullang, J. Rajagukguk, Learning Management System (LMS) Based On Moodle To Improve Students Learning Activity, Journal of Physics: Conference Series 1462 (2020) 012067. doi:10.1088/1742-6596/1462/1/012067.