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Integration of Artificial Intelligence into Solving Physical Problems to Improve Pedagogical Competence

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ABSTRACT

Purpose: To study the possibility of integrating artificial intelligence (AI) technologies in teaching the course "Workshop on solving physical problems" using neural networks in order to increase the effectiveness of the educational process. **Method:** The sampling methodology includes the analysis of data on the results of students' tasks collected during the workshop, using machine-learning algorithms to classify and predict the results. Methods of statistical data processing and visualization of results were used for the analysis, which allowed not only to identify key problems in learning, but also to offer recommendations for their elimination. **Findings:** Innovative approaches based on machine learning technologies provide flexibility in adapting course content, improving students' perception of the material and developing teachers' methodological competencies. This is especially important in the context of the increasing complexity of educational programs and the need to take into account the diversity of the level of training of students. **Implications for Research and Practice:** The results of the study demonstrate a significant improvement in the quality of teaching and the perception of the material by students, as well as an increase in the professional competencies of teachers. However, the methodology has limitations related to the quality of the source data and the need for a long period of technology implementation to assess its effectiveness. It is recommended to further develop data analysis technologies and train teachers to optimize the use of AI in educational processes.

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Introduction

Modern education is going through a period of significant changes due to the rapid development of digital technologies and the introduction of innovative approaches to learning (Ilkka, 2018). One of the key trends is the integration of artificial intelligence

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technologies into the educational process, which opens up new opportunities for improving the effectiveness of teaching and professional growth of teachers. Artificial intelligence provides tools for automating routine processes, personalizing educational content and analyzing big data, which allows for a deeper understanding of the needs and level of training of students (Kamalov et al., 2023). The use of Artificial intelligence technologies in the teaching of natural science disciplines, such as physics, where practical exercises and problem solving play a significant role, is becoming especially relevant (Abaniel, 2021). A course like physics is an important component of the training of specialists in this field, as it develops the skills of analytical thinking, experimentation and the application of theoretical knowledge in practice. However, traditional teaching methods often face difficulties associated with a lack of individualization of learning and limited time to work with each student.

The integration of the technology used in this course can significantly improve both the learning process and the pedagogical competence of teachers. Artificial intelligence is able to automate many aspects of working with tasks, such as evaluating results, making individual recommendations and analyzing typical errors (Velarde, 2020). In addition, technology provides teachers with the opportunity to expand their methodological competencies, which ultimately contributes to better training of students and improving their academic performance (e Silva et al., 2023). Teacher competence, especially in the context of technology integration into educational processes, is becoming a key approach to improving the quality of education. The use of this technique can significantly enhance pedagogical competence by developing skills in analyzing, interpreting data and modeling physical processes. The tools using the techniques allow you to visualize complex processes that are difficult to explain on a theoretical level. The teacher should be competent in creating interactive simulations that help students better understand physical phenomena through visual images and data. This may include modeling of motion trajectories, changes in system parameters, as well as real-time analysis of experiments (Salvatore & Wolbring, 2022).

The developed methodology helps to implement personalized approaches in teaching, providing students with adapted assignments based on their current level of training. The teacher adjusts the algorithms of this technology to track the progress of students, suggestions for improving their skills and automated verification of problem solutions. This approach encourages self-control and independent learning, which is an important component of pedagogical competence. Using the methods and tools of the technology used, the teacher can effectively evaluate both the individual achievements of students and the overall results of the course. Automated data analysis systems allow the teacher to quickly identify weaknesses in students' understanding of key concepts and make adjustments to the learning process. This contributes to the improvement of pedagogical efficiency and the development of competence in the organization of the educational process (Raban, 2022).

The integration of machine learning technology into the course requires a high level of professional competence from the teacher. Knowledge in the field of both physics and artificial intelligence technologies is needed in order to effectively use them in the educational process. The ability to develop adaptive systems, visualize complex processes and maintain an individual approach to each student are key approaches to pedagogical competence in modern education. The purpose of this study is to consider the possibilities of integrating neural network learning technologies into the course to increase the pedagogical competence of teachers and improve the educational process.

Literature Review

The integration of artificial intelligence technologies into the educational process has become one of the most discussed topics in modern pedagogical and scientific literature (Asad et al., 2023; Kamalov et al., 2023; Kučak et al., 2018; Xu & Ouyang, 2022; Zakaryan, 2021). The issues of using machine learning technology to solve educational problems are addressed in the works of both domestic and foreign authors, and cover a wide range of areas, ranging from adaptive learning to automation of knowledge assessment processes. One of the key approaches to integrating a neural network into education is adaptive learning. Research (Salvatore et al., 2022) emphasize that deep learning systems are able to analyze the successes and mistakes of each student, offering individualized tasks and learning trajectories. This allows each student to move at their own pace and receive more accurate recommendations based on their level of knowledge. In the course, such systems can become indispensable assistants for both students and teachers, providing a personalized approach and increasing motivation to learn.

Another important area of research is the automation of knowledge assessment. Gulian et al. (2019) argue that machine learning-based systems are able to objectively and quickly evaluate the results of tasks, which is especially important when working with large groups of students (Hu, 2023). In the course of a physical workshop, this can be useful for checking solutions to problems, analyzing typical errors and identifying gaps in students' knowledge (Taye, 2023). For example, algorithms can automatically analyze and verify solutions to problems, providing teachers with detailed information about common problems and helping to quickly make adjustments to the educational process. An important place in the scientific literature is occupied by research on the role of technology in improving pedagogical competence by making use of deep learning and neural networks as most often used artificial intelligence methods to automate solving physics problems (Monaco & Apiletti, 2023; Naseer et al., 2024; Raissi et al., 2019; Vadyala & Betgeri, 2023).

Artificial intelligence can act as an "Assistant" for teachers, providing them with analytical data on student progress and offering recommendations for improving curricula (Khatib et al., 2022). In this course, you can create interactive learning platforms that will help teachers plan classes more effectively, select assignments and track the progress of each student. The results of (Keshavarz & Ghoneim, 2021) point out that the use of digital technologies contributes not only to improving the quality of teaching, but also to increasing the level of professional competence of teachers, as they gain access to new methodological tools and technologies. In addition, research studies like (Manuel et al., 2022). A systematic review of deep learning approaches (Alnasyan et al., 2024; Chao et al., 2022) show that deep learning systems can play a key role in visualizing complex physical processes, which is especially important for students who have difficulties with abstract concepts (Du, 2023; Iten et al., 2020). Interactive simulations and virtual laboratories created using a neural network make it possible to explain many physics phenomena more clearly and help students better understand the material (Tyack et al., 2024). This, in turn, significantly increases the level of training of future specialists (Vadyala et al., 2023; Yu et al., 2022).

Research Methodology

Research Design

This research is based on the application of machine learning technologies in education, particularly on methods of teaching physics. The study programs of various educational institutions, materials on pedagogical competence and adaptive learning technology were analyzed. The theoretical materials made it possible to build a general concept and structure a plan for the introduction of a neural network into the educational process (Sailaja et al., 2023). This study was based on the premise that neural networks can be used to solve complex differential equations, even if the exact analytical solution is unknown, since neural networks are trained to solve the heat equation and allows you to approximate its solution that satisfies the specified initial and boundary conditions.

Data Collection

As part of the study, a survey was conducted using an online questionnaire. The questionnaire included the question: "Which of the listed artificial intelligence methods are most often used to automatically solve physical problems?" Data was collected at the time of solving problems, the number of errors and the level of understanding of the material.

Sampling and Research Procedure

97 respondents took part in the survey. The participants represented an audience with knowledge in the field of artificial intelligence and physics, including teachers, students and researchers. Two groups were created to conduct the study: a control group and an experimental group. The control group was trained using traditional methods of solving physical problems, while the experimental group used intelligent systems. The same tasks in both groups made it possible to objectively assess the impact of new technologies on the educational process.

Data Analysis

The effectiveness of neural network integration was assessed using both quantitative and qualitative analysis methods. The quantitative analysis included statistical processing of data on student academic performance before and after the introduction of artificial intelligence into the course. Qualitative analysis was conducted through surveys and interviews with teachers and students to identify subjective impressions and the degree of satisfaction with new teaching methods (Ukoh & Nicholas, 2022). Finally, the results of the survey were analyzed using data visualization (diagrams) and calculating the percentage distribution of responses.

Results

The applied methods and technologies adopted in this research made it possible to conduct a comprehensive study and evaluate the effectiveness of integrating intelligent systems into the course of a physical workshop, as well as identifying their potential to improve the pedagogical competence of teachers (Ukoh et al., 2022). This workshop aimed at assessing the use of neural networks as artificial intelligence applications to resolve a complex physical problem of thermal conductivity associated with modeling heat transfer in an inhomogeneous medium. Traditionally, we used a one-dimensional problem of temperature distribution in a rod with inhomogeneous thermal conductivity, where the properties of the material varied along the length of the rod. However, with the introduction of neural networks, it was possible to use 2-dimensional and 3-dimesional problem of temperature distribution. The experiment was conducted with the sample of the study. The study closely followed the determination of temperature fields and the dynamics of heat changes depending on time and initial conditions (Erdmann et al., 2021).

Formulation of the Problem for The Equation of Thermal Conductivity

The Physical Model

Imagine a flat thin plate, the surface of which is described by the x and y coordinates. The temperature field of the plate depends on time t which is not known

Mathematical Model

The thermal conductivity equation for a two-dimensional plate in a rectangular coordinate system, taking into account the temperature field u (x, y, t), is given by the following differential equation:

$$/t=\alpha\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right) \quad (1)$$

where: u (x, y, t) is the temperature at point (x, y) at time t,
let $\alpha=1$ be the coefficient of thermal conductivity (constant value),
- $\partial u/\partial t$ — the partial derivative of temperature over time,
- $\frac{\partial^2 u}{\partial x^2}$ and $\frac{\partial^2 u}{\partial y^2}$ the second partial derivatives of temperature in terms of spatial coordinates x and y.

Initial and Boundary Conditions
Initial conditions

At time t = 0, the temperature on the surface of the plate is zero:

$$u(x, y, 0)=0 \quad (2)$$

Boundary conditions

The temperature at the plate boundaries is maintained constant and equal to zero:

$$u(0,y,t)=u(x,0,t)=u(L_x,y,t)=u(x,L_y,t) \quad (3)$$

where L_x и L_y — re the dimensions of the plate along the x and y axes.

Task: It was necessary to find a solution to the thermal conductivity equation for the function u(x,y,t) with the initial temperature distribution described above.

Required: To plot the temperature field changes over time. Visualize the change in the temperature distribution on the surface of the plate at different values of t.

In order to solve the equation of thermal conductivity, we apply the Fourier transform with respect to the spatial variables x and y. The Fourier transform allows you to move from a partial differential equation to an ordinary differential equation for the Fourier image.

Direct Fourier Transform in X And Y

Let's apply the two-dimensional Fourier transform with respect to the variables x and y to the equation:

$$\hat{u}(k_x,k_y,t)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} u(x,y,t)\, e^{-i(k_x x+k_y y)}\, dxdy \quad (4)$$

The transformed equation of thermal conductivity becomes:

$$\frac{\partial \hat{u}(k_x,k_y,t)}{\partial t}=-\alpha(k_x^2+k_y^2)\,\hat{u}(k_x,k_y,t) \quad (5)$$

The ordinary differential equation (5) is solved by the method of separation of variables. Solution (5) will look like:

$$\hat{u}(k_x,k_y,t)=\hat{u}(k_x,k_y,0)\, e^{-\alpha(k_x^2+k_y^2)t} \quad (6)$$

where $\hat{u}(k_x, k_y, 0)$ the image of the initial condition.

Inverse Fourier Transform

To return to physical space, we apply the inverse Fourier transform:

$$u(x,y,t)=\frac{1}{(2\pi)^2}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \hat{u}(x,y,t)\, e^{-i(k_x x+k_y y)}\, dk_x\, dk_y \quad (7)$$

Now let's apply the Laplace transform with respect to the time variable t. It helps to solve the problem with time derivatives. Let's apply the Laplace time transformation:

$$L\{u(x,y,t)\}=\tilde{u}(x,y,s)=\int_0^{\infty} u(x,y,t)e^{-st}\, dt \quad (8)$$

The equation of thermal conductivity after the Laplace transformation will take the form:

$$s\tilde{u}(x,y,s)-u(x,y,0)=\alpha\left(\frac{\partial^2 \tilde{u}(x,y,s)}{\partial x^2}+\frac{\partial^2 \tilde{u}(x,y,s)}{\partial y^2}\right) \qquad (9)$$

where $u(x, y,0)$ is the initial condition.

The differential equation (9) in spatial coordinates x and y is solved using methods of separation of variables. The solution will be the sum of the Fourier functions in spatial coordinates and the exponential function in s.

To return to the function $u(x,y,t)$, we apply the inverse Laplace transform:

$u(x,y,t)=L^{-1} \tilde{u}(x,y,s)\}$

After the forward and reverse transformations and applying the initial (2) and boundary conditions (3), we obtain an analytical solution $u(x,y,t)=txy\sin(x)\cos(x)$, the graph of which is shown in Figure 1. The study of this problem can expand the understanding of heat transfer processes and help to develop more effective methods for calculating thermal regimes in complex technical devices.

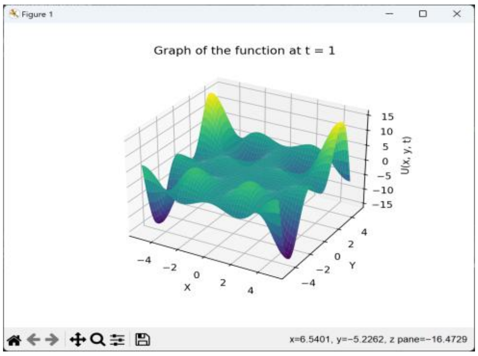

Figure 1: *Plate Temperature Change.*

Preparation of a Neural Network

Steps to solve the problem of equation (1) with initial (2) and boundary conditions (3) of thermal conductivity using a neural network. To solve the problem with a neural network, PINN models the function $u(x,y,t)$ using a neural network and_θ(x,y,t), where θ are the parameters of the neural network. The training of the neural network will be aimed at ensuring that this network approximates the solution of the heat equation.

Program Description

PINN model: A neural network with several hidden layers, it receives x,y,t at the input, and predicts the temperature $u(x,y,t)$ at the output.

Setting The Task

- Input data of the neural network: x,y,t (spatial coordinates and time).
- Output value: $u(x,y,t)$ predicted by the network.
- The task is to minimize the difference between the network and the physical equation of thermal conductivity.

Formulation of losses (loss function)

The loss function in PINNs includes several components:

- The condition of the thermal conductivity equation: it is checked how well the predicted value of $u_\theta(x,y,t)$ satisfies the original equation.

- Initial and boundary conditions are taken into account by adding losses for network values at the boundaries.

The loss function consists of two components:

- Checking the fulfillment of the thermal conductivity equation (the main equation).
- Checking the fulfillment of boundary conditions.

The model is trained using the gradient descent method, minimizing the loss function. After the simulation is completed, temperature distribution graphs are plotted. For the two-dimensional case, the temperature distribution graph at t = 1 is shown in Figure 2. This graph shows temperature changes depending on the x and y coordinates, allowing you to visualize temperature fields on the plane (Manuel et al., 2022).

For the three-dimensional case, at z = 0, the temperature distribution graph is shown in Figure 3. Here the temperature is represented as a function of the x and y coordinates at a fixed value of z, which allows you to analyze the temperature distribution on one of the selected planes in three-dimensional space. Both graphs help to better understand the behavior of the thermal process depending on temporal and spatial parameters, which is important for subsequent analysis and application in engineering tasks.

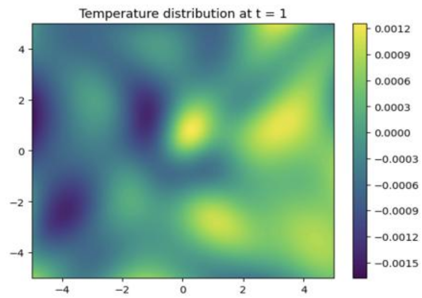

Figure 2: *Two-Dimensional Case.*

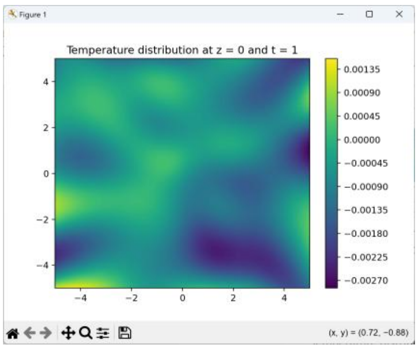

Figure 3: *Three-Dimensional Case.*

This experiment made it evident that neural networks can be used to solve complex differential equations, even if the exact analytical solution is unknown. PINNs use physical laws, which helps to improve the generalizing ability of the model and speed up learning. This neural network is trained to solve the heat equation and allows you to approximate its solution that satisfies the specified initial and boundary conditions (e Silva et al., 2023).

Keeping the study objectives in mind, three methods were used to assess the implementation and integration of artificial intelligence into teaching physics. The first method was the analysis of literature sources and reviews of modern artificial intelligence technologies. This method was used to understand the current level of research and practices for use in educational processes. Modern publications devoted to the automation of learning, personalization of the educational process and application for solving educational tasks were analyzed. Special attention was paid to adaptive learning methods and interactive educational systems. The second method was to understand the development and implementation of adaptive algorithms of an intelligent system in the educational process. This is one of the key research methods to create and test adaptive algorithms that allow the system to automatically select study assignments for students based on their current level of knowledge. These algorithms used machine learning to analyze students' successes and mistakes and adapt the complexity of assignments (Nordin et al., 2023). During the development process, different levels of complexity of physics problems were taken into account, as well as typical errors encountered by students when solving them.

The third method was using machine learning algorithms to automatically verify problem solutions. Machine learning algorithms have been developed and applied to automate the verification process of problem solutions. These algorithms allowed the system to analyze and evaluate the correctness of students' tasks, as well as provide automated feedback on typical errors. The tasks were checked automatically, taking into account complex physical calculations and possible solutions. This is an important area of research was the development and implementation of interactive simulations that allow students to visualize physical processes and experiments. This method involved the use of machine learning technologies to simulate and control various parameters of physical processes. Such simulations helped students better understand abstract concepts by visualizing complex physical laws and phenomena.

After the data collection, qualitative and quantitative analyses were done to check the effectiveness of artificial intelligence applications in the educational process. Specifically, quantitative and qualitative analysis methods were used to evaluate the effectiveness of neural network integration into the workshop. The resultant quantitative data included students' academic performance before and after the introduction of machine learning methods; time spent on solving problems; the number and nature of typical errors. The qualitative analysis included a survey of students and teachers to identify the level of satisfaction with the educational process; interviews with teachers to assess their pedagogical competence and experience working with new technologies. Thus, scientific literature testified to the high potential of the technology used to improve the educational process and increase the competence of teachers. The introduction of realizable technologies into the course can not only simplify and speed up the verification of students' decisions, but also create more personalized, adaptive and visualized training methods. Figure 4 is evident of the use of deep learning and neural networks as most often used artificial intelligence methods to automate solving physics problems. This data was collected from the sample of 97 respondents of the study.

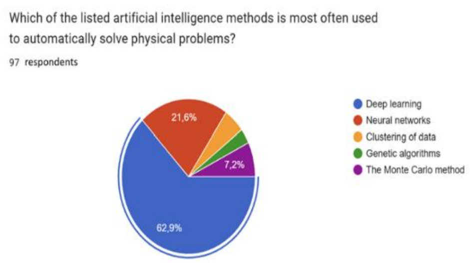

Figure 4: *The Results of Students' Responses.*

The purpose of the study was to determine which artificial intelligence methods are most often used to automatically solve physical problems, based on the opinions of respondents. Figure 1 clearly shows that deep learning was chosen by 62.9% of respondents, which demonstrates its popularity for solving physical problems. The popularity of deep learning methods confirms that this method is a dominant automatic solution of physical problems. This is due to its ability to analyze complex data structures and create accurate predictive models. This was followed by neural networks method with 21.6%, indicating the significant popularity of this method. The neural networks method was liked by respondents due to its effectiveness in solving physical problems and the simplicity of implementing basic models, though it is a part of deep learning. The other artificial intelligence methods included clustering of data liked by 7.2%, demonstrating less frequent use for tasks of this type, while the other two methods namely genetic algorithms and the Monte Carlo method were highlighted as less in demand. These methods are used less often but they are better suited for data analysis and stochastic problems, but not as effective for complex physical models.

For the purpose of this study, the respondents were divided into two groups: a control group, which was trained using traditional methods, and an experimental group, which used machine learning technologies to solve physical problems. Both groups received the same tasks, which made it possible to objectively compare the effectiveness of different approaches and identify the advantages of using artificial intelligence. During the research, teachers actively monitored the learning process of students, collected data on the results of their work, interacted with intelligent systems and analyzed the effectiveness of the applied techniques. This data allowed us to draw conclusions about how the introduction of technology helps to increase the pedagogical competence of teachers and their ability to interact more effectively with students.

Statistical data processing methods were used to analyze the results. Data on students' academic performance, their level of understanding of the material and the quality of completed tasks were collected and analyzed. Statistical processing revealed significant differences in the results of the control (See Table 1 and Figure 5) and experimental groups (See Table 2 and Figure 6), which confirmed the effectiveness of deep learning in the educational process. The use of these methods made it possible to comprehensively assess the possibilities of integrating artificial intelligence into the training course and identify the key advantages associated with the personalization of training, automation of decision evaluation and improvement of pedagogical competence of teachers.

Table 1

Participants of control group (6B01504-Physics F0C201)

Participants	Pre-experiment Score	Post-experiment Score
Storm	65	70
Echo	70	75
Luna	68	72
Sapphire	74	77
Zephyr	72	78
Seraph	66	87
Phoenix	75	80
Falcon	69	73
Meadow	71	75
Jade	73	77
Comet	85	87
Willow	50	55
Drift	53	54
Quantum	60	63

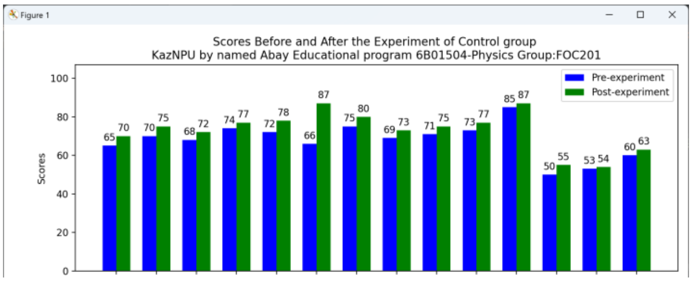

Figure 5: *Mvisualization in The Form of Diagrams of Control Group 6B01504-Physics*

Table 2

The Participants of The Experiments of Control Group 6B01504-Physics F0C201

Participants	Pre-experiment Score	Post-experiment Score
Luminous	65	85
Mystic	70	90
Celestia	68	86
Echo	74	90
Serenity	72	87
Wanderer	75	89
Dawn	75	91
Horizon	50	83
Radiance	71	88
Solstice	73	87
Reverie	83	93
Ember	57	75
Nightingale	68	84
Pioneer	71	81

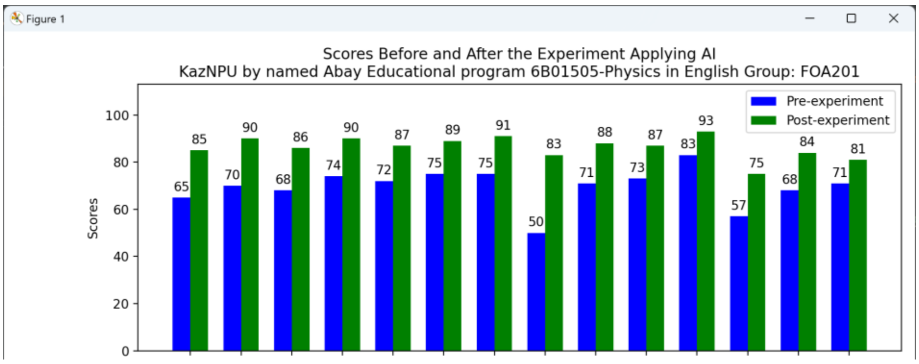

Figure 6: *Visualization in the Form of Diagrams of The Experiments of Control Group 6B01504-Physics.*

Discussion

The results of the study confirm the hypothesis that the integration of artificial intelligence technologies into the course contributes to improving the pedagogical competence of teachers and improving student academic performance. The use of this technology had a positive impact on the educational process (Al Ka'bi, 2023; Luo & Yang, 2022). The systems used made it possible to automate the selection of educational tasks for students based on their individual successes and mistakes. This contributed to the creation of a more flexible and adaptive learning environment, where each student could solve problems corresponding to his current level of training (Al-Chalabi et al., 2021). As a result, the students of the experimental group showed a higher level of understanding of the material and improved results compared to the control group, where traditional teaching methods were used. This is in line with the findings of previous studies (Chaplot et al., 2016) confirming the positive impact of adaptive learning on academic performance.

Algorithms for automatic verification of problem solutions have significantly reduced the burden on teachers, allowing them to devote more time to students who need additional help. Students received instant feedback, which accelerated the error correction process and deepened their understanding of physical principles (Cuomo et al., 2022). Moreover, teachers were able to quickly analyze typical mistakes, and made adjustments to the teaching methodology, which contributed to improving pedagogical competence through attention-based neural networks and predicting student learning outcomes (Fu et al., 2023). Interactive simulations and visualizations created using the technology under study allowed students to better understand abstract concepts that are often difficult to perceive in traditional physics teaching (Dewi et al., 2020). The students noted that such visualizations helped them to see physical phenomena in action and experiment with parameters, which improved their understanding of the material. The use of visualization in teaching physics corresponds to the conclusions of research Davis and Price (2017), which emphasizes the importance of visual methods to improve the quality of education in the natural sciences. Nwankwo and Eke (2021) discovered visualization fostering secondary school students' achievement in physics using brain-based learning instructional strategy. The integration of artificial intelligence has given teachers new tools to improve teaching. They were able to use the data collected by the system to analyze students' academic achievements and improve their methods. The opportunity to monitor the individual progress of each student allowed teachers to better understand the weaknesses and strengths of students and adjust the learning process in real time. Thus, the teachers not only improved their methodological skills, but also increased their general pedagogical competence (Ilkka, 2018).

Despite the obvious advantages, the integration of the technology used in the educational process requires significant resources, both temporary and technical. The teachers noted that at the initial stages of the implementation of the methods, it took time to learn and adapt to new technologies. Technical limitations related to the lack of flexibility of some intelligent systems were also identified, which sometimes led to incorrect interpretation of students' decisions. This confirms the conclusions of other studies (Yeadon & Hardy, 2024), which mention the difficulties associated with the introduction of artificial intelligence into traditional educational processes to teach physics or conduct research in physics (Erdmann et al., 2021; Farea et al., 2024). The study showed that the integration of applied technologies into the course significantly improves both student academic performance and the competence of teachers. However, the successful implementation of such solutions requires proper teacher training, technical support and regular system updates to eliminate possible shortcomings (Xu, 2024).

Thus, the results of the study confirm the significant potential of using this technology in educational practice, especially in disciplines related to solving physical problems. The identified improvements, such as improving student academic performance, developing their engagement and deeper learning of the material, coincide with the conclusions of previous studies on the use of AI in education. For example, works indicate the ability of adaptive technologies to improve learning outcomes by individualizing the learning process and automating routine tasks of teachers (Al-Chalabi et al., 2021). In addition, this study also confirms the conclusions that the integration of AI contributes to the professional development of teachers. The ability to analyze data on students' academic achievements and create personalized educational trajectories, as shown in the study, allows teachers to better understand the individual needs of students and improve teaching methods. Thus, the introduction of such technologies contributes not only to improving the quality of the educational process, but also to the development of pedagogical competence, which is an important result for the education system (Ilkka, 2018; Kamalov et al., 2023).

However, unlike most previous studies, our focus on using technology to visualize complex physical processes and automate task verification has demonstrated another advantage of AI — the ability to make the study of complex concepts more accessible and visual. This is especially true for disciplines that require abstract thinking and working with mathematical models. However, this study has revealed several limitations. The key challenge remains the need for significant time and technical resources for technology implementation, as well as teacher training. Similar limitations have also been noted in studies that focus on the long-term adaptation of teachers while blending to new technologies (Kumar et al., 2021).

The main conclusions and significance of the study included (1) confirmation of the effectiveness of AI technologies to improve the educational process, making it more efficient, individualized and focused on the needs of students. (2) Development of pedagogical competence through integration of AI and opening up new opportunities for improving the professionalism of teachers through the analysis of educational data and the adaptation of teaching methods. (3) Practical applicability as demonstrated in the need for phased implementation of AI in the educational process, taking into account resource and infrastructure requirements. The significance of this study also lies in the fact that it not only confirms the value of using AI in education, but also offers a methodological approach to its integration, which can become the basis for further development and modernization of the education system as a whole.

Conclusion

During the experiment, a software platform based on a self-learning system capable of analyzing students' academic achievements and selecting individualized tasks was used. The system was integrated into the course of the physical workshop and offered students different types of tasks depending on their level of training and academic performance. The program also analyzed typical mistakes of students and generated recommendations for the teacher to adjust the teaching methodology. One of the key elements of the study was the application of machine learning algorithms to automatically verify students' decisions. These algorithms evaluated the correctness of the tasks and provided feedback, which allowed the teacher to focus on more complex learning problems. The error analysis system helped to identify the most common difficulties that students faced when solving physical problems. Visualization and simulation systems of physical processes created using intelligent technologies were also integrated into the educational process. These tools allowed students to interact with virtual models, experiment with parameters, and better understand abstract concepts. Visualization was used to support theoretical material and problem solving.

As a result of the conducted research, significant advantages of integrating artificial intelligence technologies into the course were identified. The use of the implemented technology in the educational process allowed to improve student academic performance, increase their level of engagement and provide teachers with new tools for personalizing learning. Adaptive technologies, visualization of complex physical processes and automatic verification of problem solutions had a positive impact on the quality of learning, which led to deeper assimilation of the material. In addition, the integration of this technology contributed to the development of teachers' pedagogical competence. The ability to analyze data on students' academic achievements, customize educational trajectories and quickly identify problem areas allowed teachers to improve their methods and manage the educational process more effectively (Salvatore et al., 2022). Despite the obvious advantages, the introduction of the technology under study requires significant time and technical resources, as well as training teachers to work with new technologies. However, these efforts are justified by improving the quality of the educational process and creating conditions for more effective interaction between teachers and students.

The integration of artificial intelligence into the workshop is a promising area that can significantly improve the quality of the educational process and develop the pedagogical competence of teachers. These technologies allow you to personalize learning, automate task verification, and provide teachers with more detailed information to improve their methodological approaches. The introduction of these technologies requires initial investments and training, but in the long term they can significantly improve the learning outcomes and training of future specialists. Thus, the integration of artificial intelligence technologies into the course opens up new prospects for the modernization of the education system, contributes to the improvement of pedagogical competence and the improvement of students' academic results. The results also emphasize the importance of deep learning and neural networks in automating the solution of physical problems, while simultaneously opening up prospects for further analysis of their practical application (Tang et al., 2022).

Limitations and Recommendations

The study faced a few limitations despite its having achieved its research objectives. The first limitation is its small sample size of 97 respondents which, though is a sufficient number for preliminary analysis, a larger sample could improve the accuracy of the results. Second, this study focused more on respondents' opinions and their subjective preferences, and less on empirical data on the frequency of use of methods. This might have risked a little subjective bias in the outcomes of this research. Third, the research did not take into account the specifics of the tasks or the context of the application of the methods, which could be considered a methodological bias. Future studies should expand the sample by adding participants from various fields of physics and AI to increase the representativeness of the data. Additional research should also be conducted to analyze real cases of AI application in physics in order to confirm the subjective assessments of the respondents.it is also necessary to study the effectiveness of methods in terms of parameters such as accuracy, speed and adaptability for different types of physical tasks.

The study also found a few constraints that can potentially create challenges in introducing artificial intelligence methods in teaching of physics. One of these constraints is technical and resource costs since AI technologies require significant financial investments, for updating the technical infrastructure and ensuring the stable operation of the system. A need for trained teachers to effectively use new technologies, for which additional time and efforts should be allotted to improve the skills of teachers. Last, but not the least, the accuracy and effectiveness of machine learning algorithms directly depend on the completeness and reliability of data, which can be a challenge in an educational environment. To address these constraints, a few recommendations may be given. First, technology implementation should be planned step-by-step, first with pilot projects and in small groups to evaluate the effectiveness and then make necessary adjustments before large-scale implementation. Second, teacher training programs should be introduced to develop professional skills of teachers into AI technologies and their integration into the educational process. Third, infrastructure support should be provided which can give access to modern computing resources and software for stable operation of systems. Fourth, it is required to conduct regular monitoring and analysis of the educational outcomes in order to identify weaknesses and adapt technologies to the changing needs of the educational process. Finally, there is a need to involve experts in artificial intelligence and pedagogy to develop and improve adaptive educational technologies. In the long term, the integration of AI into the educational process will significantly improve the quality of education, training of specialists and increase the level of professional competence of teachers.

Author contributions

All authors have equally contributed to the study and agree with the results and conclusions.

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