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THE SCIENTIFIC AND THEORETICAL FOUNDATIONS OF MODELING EXPERIMENTAL PROCESSES BASED ON ARTIFICIAL INTELLIGENCE

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ANNOTATION *This article examines the scientific and theoretical foundations of modeling experimental processes using artificial intelligence (AI). It provides a comprehensive analysis of how AI technologies enable the reconstruction of experimental systems in digital environments, the development of virtual models that closely resemble real conditions, and the prediction of probabilistic outcomes under complex interactions. Machine learning, mathematical modeling, statistical analysis, digital twin technology, neural networks, and algorithmic forecasting are discussed as modern methodological tools that significantly enhance research efficiency. The article highlights the relevance and importance of AI-based experimental modeling, identifies existing challenges, explores scientifically grounded solutions, and proposes recommendations for further development.*

KEYWORDS: *artificial intelligence, modeling, digital twin, algorithmic analysis, experimental process, machine learning, statistical model, scientific methodology, optimization.*

INTRODUCTION

The rapid development of artificial intelligence technologies has ushered in a completely new stage in scientific research and innovation. Traditionally, experiments have played a central role in the acquisition of scientific knowledge; however, conducting real-world experiments is often labor-intensive, resource-consuming, risky, or simply impossible due to physical, chemical, biological, or environmental constraints. In such cases, AI-based modeling offers fundamentally new scientific possibilities. Through AI, researchers can reconstruct experimental processes in virtual

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environments, mathematically express complex systems, analyze object behavior, examine the effects of various parameters, forecast results, and determine the most optimal conditions. This not only simplifies the experimental process but also increases the accuracy, reproducibility, safety, and overall effectiveness of scientific research. The scientific foundations of modeling begin with the digitalization of the object under study. Physical, chemical, biological, or technological characteristics of the system are converted into numerical parameters.[40] The functional relationships between these parameters are identified and mathematically described through equations, regressions, distributions, or dynamic models. Traditional mathematical modeling assumes deterministic and strictly defined relationships, but real-world systems are inherently complex, nonlinear, and probabilistic. The advantage of AI lies in its ability to analyze such uncertain and dynamic systems without relying solely on predefined equations, instead discovering underlying patterns directly from data. AI models learn, adapt, and continuously improve over time. Machine learning algorithms expand their internal knowledge based on accumulated data, reducing errors and improving prediction accuracy. Neural networks, for instance, possess the capacity to identify hidden patterns and nonlinear interactions within complex processes. In scenarios where conducting direct experiments is costly or dangerous, a neural-network-based digital twin can simulate the entire process virtually. This ensures safe, repeatable, and scalable analysis while maintaining scientific integrity. There are numerous cases where researchers cannot intervene directly in physical systems. In environmental studies, for example, real-world experimentation may damage natural ecosystems, making virtual modeling a key tool. In technical fields, experiments under extreme temperatures, pressures, or chemical exposures pose significant risks, yet AI models can safely evaluate these conditions in digital form. In agriculture, biology, energy systems, materials science, and industrial technologies, AI-enhanced modeling provides researchers with deeper insights and more reliable conclusions. Today, the rapid development of science and technology around the world has also had a significant impact on the field of education. In particular, innovations in digital technologies and artificial intelligence (AI) are fundamentally transforming the modern education system. The use of artificial intelligence in the teaching process expands opportunities for individualized learning, automation of educational activities, accurate assessment of learners' knowledge, and the adaptation of learning materials.

[40] Karimov, A., & Jo‘rayev, M. Fundamentals of Artificial Intelligence. Tashkent: Innovatsiya Publishing, 2021.

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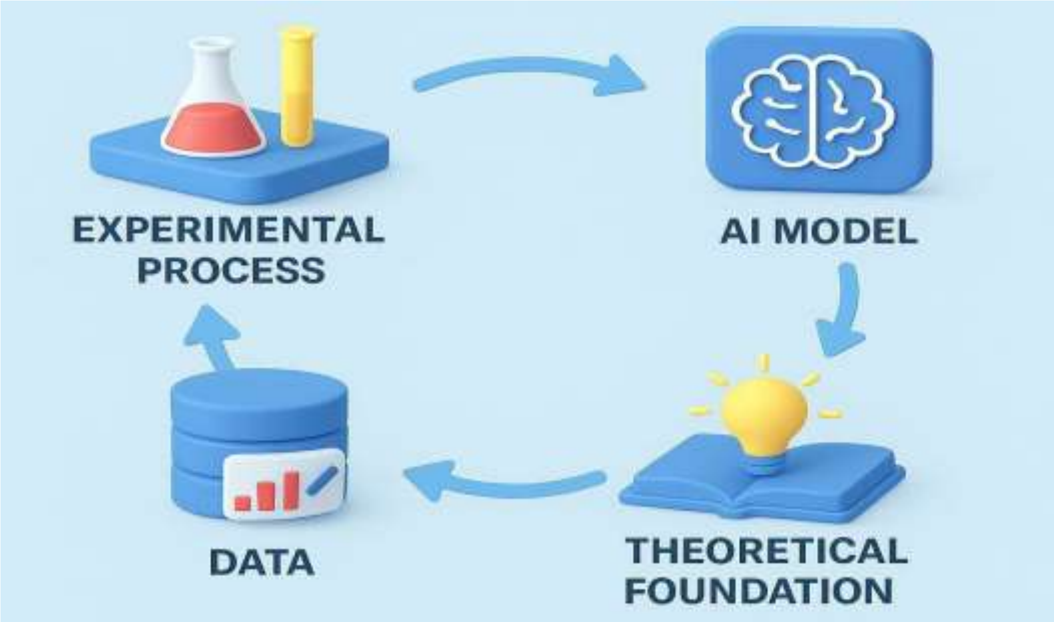

Figure 1. Schematic representation of the scientific and theoretical foundations of modeling experimental processes using artificial intelligence. The relevance of AI-based experimental modeling is increasing due to several factors. Firstly, scientific processes are becoming more complex, and traditional experiments cannot capture all influencing variables. Secondly, the rising cost of laboratory resources necessitates more efficient alternatives.[41] Thirdly, AI significantly reduces human error by analyzing vast datasets with high precision. Fourthly, AI-driven modeling supports the fast-paced development of many industries by offering quick, reliable solutions. A review of international experience shows that such technologies serve as great potential for the education sector as well. This is because AI-based intelligent systems, chatbots, virtual assistants, and personalized learning platforms help learners develop independent thinking, information analysis, critical reasoning, and innovative skills. This, in turn, is an important step in preparing the new generation for the demands of the digital world.

Scientific and theoretical foundations. Currently, there are various approaches to artificial intelligence, with differing directions and evaluation criteria. The role of artificial intelligence in the education system can be substantiated through the analysis of existing theoretical and practical studies.

For instance, John McCarthy defines artificial intelligence in two directions: first, as the creation of software tools aimed at performing cognitive processes similar to human intellectual activity; second, as the development of hardware-software systems supporting these processes. In this way, AI allows the reconstruction of

[41] Rasulov, Z. Fundamentals of Mathematical Modeling. Tashkent: TDYU Publishing, 2018.

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human thought processes and the modeling of complex decision-making activities.

A.P. Shapoval, emphasizing the importance of the scientific-technical base and information resources in societal development, considers knowledge and intellect as the main driving forces. He analyzes artificial intelligence both from a general theoretical perspective and in relation to the individual, scientifically justifying that a systematic approach to creating any material or intellectual product constitutes the methodological foundation of AI. Additionally, A.Ye. Nikitin, through the concept of "thinking machines," examines the emergence and development of AI from the 1950s and identifies classical, romantic, modernist, and postmodernist stages. This classification highlights the evolution of AI paradigms, technological capabilities, and practical applications.

In this way, the perspectives of these scholars establish the scientific-theoretical foundation of artificial intelligence and provide a methodological basis for its use in educational processes, including the modeling of learning activities, automation of educational workflows, and assessment of knowledge. Approaches related to algorithmic, cognitive, and expert systems further allow for reliable forecasting of complex processes and the substantiation of theoretical conclusions.

Methodologically, AI-based modeling requires a clear sequence of scientific procedures: collecting comprehensive data about the object; cleaning, organizing, and converting data into numerical form; identifying parameter relationships; selecting appropriate machine learning models; training the models; evaluating accuracy; and optimizing the final digital representation. Each step requires rigorous scientific justification. For example, data quality is the primary determinant of model precision; incomplete or inaccurate measurements will inevitably lead to flawed predictions. Therefore, statistical methods such as variance analysis, correlation and covariance evaluation, and probability theory remain integral components of AI-driven modeling. A significant strength of AI models is their universality. Once trained on a given system, a model can often be adapted to similar processes, generating new insights or guiding further research. In agriculture, a model developed for analyzing plant growth can be extended to other crops or used to predict environmental impacts. In industrial manufacturing, AI can recommend optimal parameters to reduce energy consumption, minimize waste, and enhance overall performance.[42] However, several challenges remain: insufficient datasets; algorithmic complexity; lack of interpretability in model outputs; discrepancies between virtual models and

[42] Xolmatov, U. Digital Twin Technology and Its Application in Industry. Tashkent: Science and Technology Publishing, 2023.

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real-world conditions; and the high cost or difficulty of collecting high-quality training data. Addressing these issues requires hybrid approaches that combine AI with traditional scientific methods, multi-layered analytical frameworks, and continuous comparison of digital twin outputs with real experiments.

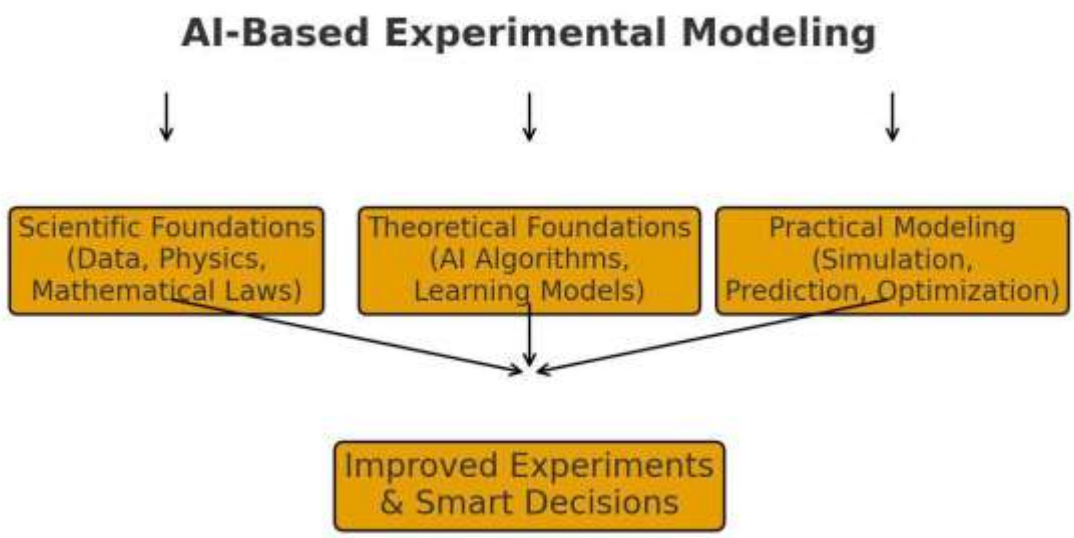

Figure 2. AI-Based Experimental Modeling

Possible solutions include: gathering data from multiple sources; enhancing statistical preprocessing; progressively training models from simple to complex structures; developing interpretable AI systems; and validating digital twins with real-time experimental feedback. These scientific approaches significantly increase the reliability of AI-based modeling.

Among the recommendations proposed by researchers are: establishing conceptual frameworks for AI integration into experimental processes; selecting algorithms based on the nature of each experiment; continuously evaluating and improving model performance; and strengthening AI competencies in scientific education and training. Considering the future trajectory of science, AI-based modeling is expected to become a core methodological tool across all research domains.

IN CONCLUSION

artificial intelligence is transforming experimental research by introducing a new conceptual and methodological paradigm. It enhances accuracy, efficiency, safety, reproducibility, and cost-effectiveness, enabling the construction of virtual environments that closely replicate real experimental

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conditions. Through AI, scientists can conduct deep analyses of complex systems, optimize parameters, predict outcomes with high precision, and derive new theoretical conclusions. Thus, the integration of AI technologies into experimental research is not only relevant but also represents one of the most promising directions for the future of science.

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