# DIDACTIC FOUNDATIONS OF SIMULATING LABORATORY PROCESSES USING ARTIFICIAL INTELLIGENCE

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**Annotation:** *This research examines the didactic foundations of simulating laboratory processes through artificial intelligence (AI) technologies. AI-based virtual laboratories create safe, cost-effective, and interactive environments where students can perform experiments, observe complex processes, and correct mistakes without risk. The study identifies the pedagogical principles required for effective integration of AI simulations into the educational process, analyzes their advantages, and evaluates their impact on the formation of practical competencies. The results demonstrate that AI-supported simulations significantly enhance students' analytical skills, experimental competence, and learning motivation.*

**Keywords:** *Artificial intelligence; laboratory simulation; virtual laboratory; didactics; educational technology; experimental competence; modeling; virtual learning.*

## INTRODUCTION

The effective organization of laboratory work is essential for developing students' practical skills and scientific thinking. However, traditional laboratory sessions often require expensive equipment, high safety standards, and specialized training conditions.[15] These limitations restrict the full implementation of laboratory activities in many educational institutions.

Artificial intelligence technologies offer new opportunities for addressing these challenges. AI-based simulations enable learners to recreate laboratory processes virtually, analyze them step-by-step, and repeat experiments without material limitations or safety concerns.

Such tools strengthen the didactic quality of laboratory instruction by providing individualized feedback, adaptive learning pathways, and interactive visualization of complex scientific phenomena. Therefore, studying the didactic foundations of AI-supported laboratory simulations is highly relevant for modern education systems.

Research Objective. Research Tasks:

1. To analyze AI-based laboratory simulations from a theoretical and methodological perspective.

2. To identify didactic principles governing the effective use of virtual laboratory environments.

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[15] Huang, R., & Hew, K. (2021). Artificial Intelligence in Education: Theory and Practice. Springer.

3. To evaluate the influence of AI simulations on students' practical and analytical competencies.

4. To develop recommendations for integrating AI-supported laboratory tools into educational practice.

To substantiate the didactic principles and pedagogical effectiveness of using artificial intelligence to simulate laboratory processes in educational settings.

Methodology. This principle directly aligns with the use of AI-based laboratory process simulation, where learners are placed in open-ended, problem-solving environments. AI simulations allow students to experiment, make decisions, observe outcomes, and correct mistakes without real-world risks. Designing open-ended tasks within AI virtual labs helps reveal students' prior knowledge and encourages deeper conceptual understanding.[16] The research is based on a combination of qualitative and analytical methods, including:

Literature Review: Analysis of international and local studies on AI in education, virtual laboratories, and digital didactics.

Comparative Analysis: Examination of differences between traditional and AI-based laboratory instruction.

Pedagogical Analysis: Assessment of didactic principles, teaching functions, and learning outcomes associated with AI simulations.

Synthesis Method: Integration of theoretical findings to develop methodological recommendations for educators.

No empirical experiment was conducted; the study relies on theoretical and conceptual analysis.[17]

Main Findings. 1. AI improves the accessibility of laboratory work: Students can perform experiments without physical equipment, safety risks, or financial constraints.

2. Virtual simulations strengthen analytical skills: AI systems allow learners to visualize reactions, track variables, and understand multi-step processes in detail.

3. Safe error identification: Students can detect and correct mistakes without real-world consequences, supporting deeper conceptual understanding.

4. Personalized learning pathways: AI analyzes students' actions and provides individualized feedback and adaptive suggestions.

5. Enhanced motivation and engagement: Interactive simulations increase student interest and reduce anxiety associated with real laboratory tasks.

6. Didactic effectiveness: AI-based laboratories support learner-centered education, repeatability of experiments, and independent knowledge construction.

7. Relevance for STEM education: Particularly useful in chemistry, biology, physics, engineering, and medical training due to complex practical requirements.

AI simulations support independent learning, helping students derive complex procedures and understand concepts deeply. Open-ended virtual labs encourage exploration and problem-solving rather than memorization.

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[16] UNESCO. (2022). AI in Education: Global Review.
[17] Miller, T. (2020). AI-Driven Learning Environments. Springer.

Conclusion. AI-based laboratory simulations offer significant pedagogical advantages and represent an essential innovation in modern education.

They improve the quality of laboratory instruction by providing safe, interactive, and repeatable experimental experiences.

By strengthening students' practical competencies and analytical thinking, AI-supported simulations enhance both traditional and distance learning formats.

The study concludes that integrating AI into laboratory education not only modernizes the learning process but also contributes to the preparation of highly skilled specialists in STEM fields. Continued research is recommended to develop comprehensive didactic models for AI-supported laboratory environments.

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