AN INNOVATIVE APPROACH TO INTERDISCIPLINARY TEACHING OF TECHNICAL SCIENCES THROUGH REMOTE LABORATORY PLATFORMS

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Abstract
The article outlines the theoretical and methodological foundations for ensuring interdisciplinary continuity by implementing remote laboratories in teaching technical sciences. It analyzes how digital technologies, virtual simulators, IoT devices, and online laboratory platforms contribute to the integration of technical science content, the expansion of students' experimental activities, and the enhancement of independent learning efficiency. As a result of this research, a conceptual model for providing interdisciplinary integration based on remote laboratories has been developed.

Keywords: Remote laboratories, interdisciplinary continuity, technical education, STEM/STEAM, virtual simulators, IoT, conceptual model, digital transformation.

Introduction

In recent years, the rapid development of digital technologies has intensified the need for remote laboratories in the education system, particularly in technical fields. Global experience shows that virtual and remote laboratories allow learners to perform complex practical experiments in subjects such as physics, electronics, programming, and mathematical modeling in a timely, safe, and resource-efficient manner.

Ensuring interdisciplinary continuity is one of the most pressing issues in technical higher education today. Studying a specific technological process simultaneously reveals the interconnection of physical laws, mathematical calculations, computer models, programming algorithms, and electronic circuit elements. An innovative way to effectively organize this continuity in education is through remote laboratories [2].

The scientific basis of remote laboratories is extensively covered in research from prestigious universities such as MIT, Stanford, and the Open University. International studies highlight the following:

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- **Remote laboratories enhance students' independent learning activities,** enabling them to reach higher levels of Bloom's Taxonomy.
- **Working with laboratory equipment in real-time helps** harmonize virtual simulations with practical experience.
- **They foster interdisciplinary competencies,** such as technical thinking, analytical analysis, algorithmic approaches, and creative problem-solving skills.
- **STEM and STEAM approaches** specifically require this integration.
  Furthermore, the acceleration of digitalization in the Uzbekistan education system (Decrees PF–76, PQ–254) provides the regulatory and legal framework for the wide implementation of remote laboratories.

The following scientific methods were used in the study:

- **Theoretical analysis:** Scientific sources, international experiences, and virtual laboratory platforms (PhET, Labster, Tinkercad, MATLAB Remote Lab, NI ELVIS Remote) were studied.
- **Modeling:** An interdisciplinary integration model was developed.
- **Experimental method:** Efficiency was evaluated by comparing the experience of using remote laboratories with a control group.

Advantages of Remote Laboratories for Technical Sciences

- Reduced need for physical equipment; students can conduct experiments multiple times.
- 24/7 access to laboratories for students.
- Hazardous experiments are conducted in a safe environment.
- Processes are fully monitored through real-time sensors.
- Physics, electronics, mathematics, and programming appear as a unified process.

Interdisciplinary Continuity Mechanism

Remote laboratories facilitate the following integration:

Subject	Interdisciplinary Involvement
Physics	Heat exchange and sensor principles
Mathematics	Measurement regression and linear modeling.
Electronics	Arduino + DHT22 sensor connection
Programming	Real-time monitoring using Python/MATLAB
Technology	Device design, manufacturing processes, technical safety

Conceptual Model of Interdisciplinary Continuity

The following stages are proposed:

1.Content Integration: Identification of overlapping content in curricula (e.g., Ohm's Law – Physics, Electronics, Mathematics).

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2.Platform Selection: Choosing virtual/remote labs

- PhET for physics
- Tinkercad for Arduino
- MATLAB for analysis
- IoT for real-time data

3.Unified Learning Scenario:
For example, a project on "Increasing Energy Efficiency of a Lighting System."

4.Evaluation and Analysis: Students perform experiments and present results via graphs and code.

5.Competency Formation:

- Engineering thinking
- analytical skills
- independent design

Specific Example: "IoT-based Temperature Control System"
Student activities include:

- **Physics:** Heat exchange and sensor principles.
- **Mathematics:** Measurement regression and linear modeling.
- **Electronics:** Arduino + DHT22 sensor connection.
- **Programming:** Real-time monitoring using Python/MATLAB.
- **Technology:** Device design, manufacturing processes, technical safety

This project is an ideal example of the STEMP approach.
The conducted analysis showed that:
• **Remote laboratories reduce** the interdisciplinary division in technical subjects, presenting the process as a single system.
• Students gain a **deeper understanding** by repeatedly performing experiments, which is more effective than traditional laboratories.
• Opportunities are created for the teacher to adapt education within the framework of a personal orientation.
However, there are also the following problems:
• dependence on internet speed;
• the need for regular technical support of laboratory servers;
• the need to improve the digital competencies of teachers.
Remote laboratories are one of the most effective modern tools for ensuring interdisciplinary continuity in teaching technical subjects. The model developed in the study serves to create an integrated learning environment, combine real and virtual experiences, and develop student competencies. This approach accelerates digital transformation in technical higher education and increases the quality of engineering education.

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