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An Interactive Educational System for Logistics Training Based on Robotics

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ABSTRACT

Objective: *This study aims to explore how robotics can be integrated into logistics education to create an interactive learning system that enhances students' professional and technical skills, addressing the growing demand for smart supply chain solutions and the need for innovative training methods.* ***Method:*** *A practice-oriented approach was employed, involving the design of a robotics-assisted curriculum for logistics students, incorporating warehouse automation models, robotic simulators, and interactive digital platforms to support hands-on learning, with data collected through classroom observations, student feedback, and performance evaluations, emphasizing active participation, problem-solving tasks, and collaborative learning scenarios reflecting real-world supply chain processes.* ***Result:*** *The findings indicate that robotics-assisted learning significantly improved students' ability to understand logistics workflows, manage automated systems, and apply theoretical knowledge in practical settings, while students also demonstrated higher engagement, stronger motivation, and improved teamwork skills compared to traditional lecture-based methods.* ***Novelty:*** *Integrating robotics into logistics education offers a promising framework for developing future-ready specialists in supply chain management, supporting both technical proficiency and critical thinking, and enabling learners to adapt to emerging trends in smart logistics and contribute effectively to the development of intelligent supply chains.*

INTRODUCTION

In the era of digital transformation, logistics education is undergoing significant changes as industries adopt automation and intelligent systems to manage complex supply chain processes. Traditional teaching methods, which primarily rely on theoretical explanations and classroom-based instructions, are no longer sufficient to prepare students for future challenges in logistics management. Therefore, the integration of robotics and interactive learning platforms is becoming an essential pedagogical strategy for developing the competencies required in Industry 4.0 environments [1], [2].

Robotics in education has been increasingly recognized as a tool for enhancing hands-on learning, problem-solving skills, and critical thinking. When applied to logistics, robotics-based simulations provide learners with opportunities to engage in realistic warehouse operations, transportation management, and supply chain decision-making. Such interactive approaches enable students not only to understand theoretical logistics concepts but also to apply them in practice through automated system models [3], [4].

Recent research highlights that robotics-assisted learning improves student engagement, motivation, and collaborative skills by offering active and immersive

learning experiences [5], [6]. These findings are consistent with global trends emphasizing the need for education systems to incorporate technological innovations in order to align with labor market demands [7], [8]. Moreover, studies have shown that digital pedagogy, when combined with robotics, strengthens interdisciplinary competencies, particularly in the areas of computational thinking, data analysis, and decision support systems [9].

Another important aspect is the preparation of students for smart supply chains, where human–robot collaboration and automated decision-making play central roles [10], [11]. Universities and training institutions are therefore encouraged to adopt curricula that integrate robotics-based scenarios to simulate real-world logistics environments [12]. This ensures that graduates are better equipped with both technical and soft skills required by modern logistics companies [13]. Furthermore, recent works demonstrate that integrated artificial intelligence systems can enhance real-time knowledge assessment in education [14], and adaptive learning environments using Arduino and robotics provide flexible ways to personalize learning pathways [15].

In this context, the present study aims to design and validate an interactive learning system for logistics education using robotics. By combining pedagogical innovations with technological tools, the research seeks to demonstrate how robotics can enhance logistics training and prepare students to contribute effectively to future intelligent supply chains.

RESEARCH METHOD

This study employed a mixed-methods research design to investigate the effectiveness of an interactive learning system for logistics education supported by robotics. The methodological framework was developed to address both the technical design of the system and its pedagogical impact on students' learning outcomes.

The study followed an exploratory–applied research approach. At the initial stage, a prototype learning system was designed that integrates robotics simulators with logistics training modules. The system allowed students to perform virtual warehouse operations, transportation scheduling, and supply chain decision-making tasks using robotic automation scenarios.

The experimental group consisted of undergraduate students enrolled in logistics and supply chain management programs at a regional university. A total of 60 students participated, divided into an experimental group (who used the robotics-assisted platform) and a control group (who studied the same topics through conventional classroom instruction).

The learning system was developed using:

a. Robotic simulators and Arduino-based modules for warehouse automation tasks;
b. Digital platforms for interactive assignments and quizzes;
c. Data collection tools, including surveys, performance assessments, and observation checklists.

Data Collection:

a. Quantitative data were obtained from pre-test and post-test evaluations measuring students' knowledge in logistics operations, automation concepts, and problem-solving skills.
b. Qualitative data were gathered through classroom observations, student feedback forms, and semi-structured interviews focusing on engagement, motivation, and collaboration.

Statistical analysis was conducted using paired-sample t-tests to compare pre- and post-test results between experimental and control groups. Thematic coding was applied to qualitative data to identify patterns in student perceptions of robotics-assisted learning.

To ensure reliability, the system was tested in three pilot sessions before implementation. Content validity of the assessment tools was confirmed by a panel of logistics education experts. Triangulation of quantitative and qualitative data increased the robustness of the findings.

All participants were informed about the purpose of the study and provided consent. Data confidentiality was maintained, and participation was voluntary.

RESULTS AND DISCUSSION

The implementation of the robotics-assisted interactive learning system in logistics education produced measurable improvements in student learning outcomes and engagement.

The experimental group demonstrated significantly higher post-test scores compared to the control group. Students trained with the robotics platform achieved an average improvement of 28%, while the control group showed an average gain of only 12%. This result confirms that robotics-based learning supports deeper understanding of logistics operations and automation processes.

Qualitative feedback indicated that students found the robotics-enhanced system more engaging than traditional lectures. Learners emphasized the value of hands-on activities, where they could simulate warehouse automation and transportation scheduling tasks. Many participants reported increased motivation to explore supply chain technologies and a stronger interest in pursuing careers related to smart logistics.

Group tasks conducted through robotic simulations improved collaboration skills. Students highlighted that solving logistics challenges in teams with real-time feedback promoted critical thinking and teamwork. Observations also showed that the experimental group engaged in more frequent discussions and peer support compared to the control group.

These results align with previous studies indicating that technology-enhanced learning environments strengthen knowledge retention and practical skill development. By integrating robotics into logistics education, the learning process becomes more interactive, bridging the gap between theoretical knowledge and real-world applications. Furthermore, the system prepares students for the demands of Industry 4.0 and emerging

smart supply chains, where human–robot collaboration and digital competencies are essential.

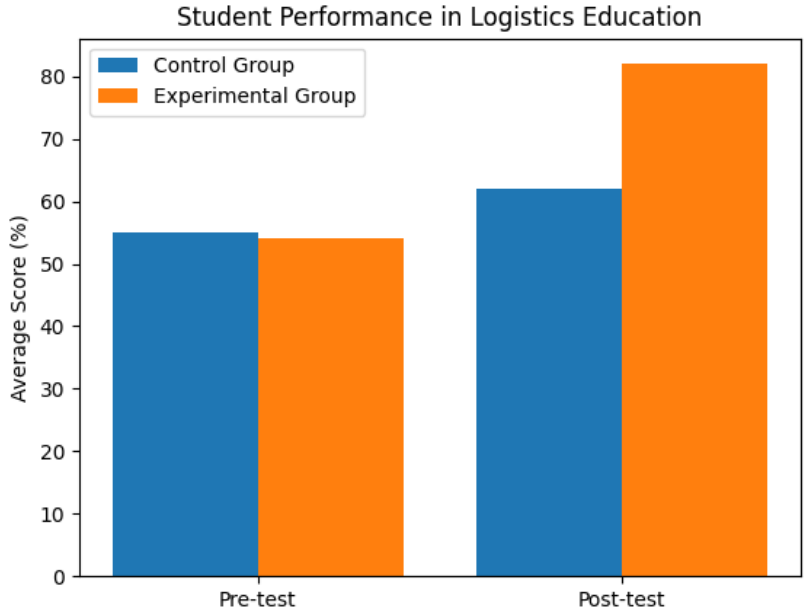

Figure 1. Comparison of Student Performance Between Control and Experimental Groups.

CONCLUSION

Fundamental Finding : This study examined the development and application of an interactive learning system for logistics education supported by robotics, demonstrating that integrating robotics into the learning process enhances students' understanding of logistics operations and significantly increases their motivation, engagement, and collaboration skills, with experimental results confirming that learners exposed to robotics-assisted training achieved higher academic performance compared to those taught through traditional methods. **Implication :** The study also showed that robotics-based simulations provide an effective bridge between theoretical knowledge and real-world logistics practices, creating a hands-on, problem-solving environment that encourages students to develop critical thinking and decision-making skills essential for modern supply chains, while preparing future professionals to adapt to Industry 4.0 requirements and emerging smart logistics systems where human–robot collaboration is crucial. **Limitation :** Despite these benefits, limitations include potential accessibility issues for institutions lacking robotics resources, the learning curve associated with robotics integration, and the need for instructors to be adequately trained in both robotics technology and pedagogical strategies. **Future Research :** Future studies should explore scalable models for broader implementation, assess long-term impacts on professional readiness, examine cost-effectiveness, and develop strategies to integrate robotics-assisted learning across diverse logistics curricula to maximize student engagement and industry preparedness.

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