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PEDAGOGICAL CONDITIONS FOR THE DEVELOPMENT OF PROFESSIONAL COMPETENCIES IN FUTURE ELECTRICAL ENGINEERS

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Abstract

This article analyzes a system of pedagogical conditions aimed at developing the professional practical competencies of future electrical engineers through the four main sections of the Electrical Machines course: transformers, induction machines, synchronous machines, and DC machines.

For each section, engineering tasks specific to different types of electrical machines, practical and laboratory activities based on real industrial production processes, pedagogical methods, project-based learning, modeling, and integration with industrial practice were implemented.

The study employed a competency-oriented instructional model that combines theoretical knowledge with practical engineering applications. The results of an experimental study involving 256 students conducted between 2023 and 2026 demonstrated that the experimental group achieved significantly higher levels of technical calculation, design, and practical skills compared to the control group, with an average increase of 27.8 percentage points.

These findings confirm the effectiveness of the proposed pedagogical conditions in enhancing the professional competencies of future electrical engineers.

Keywords: Engineering education, electrical engineer, electrical machines, transformers, asynchronous machines, synchronous machines, AC machines, professional competence, pedagogical conditions.

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Introduction

The Electrical Machines course is a fundamental component of electrical engineering education. Within this course, students study the structure, operating principles, and practical applications of transformers, induction machines, synchronous machines, and direct current (DC) machines. These devices constitute essential elements of modern power systems, industrial production, and transportation infrastructure.

In particular, transformers are widely used in the transmission and distribution of electrical energy over long distances. In industrial enterprises, induction machines serve as the primary electric drives for various technological mechanisms, electric motors, pumps, ventilation systems, and conveyor installations. The generation of electrical energy at power plants is mainly performed by synchronous generators. Furthermore, in the transportation sector, especially in metro systems, trams, and electric locomotives, DC machines remain important due to their convenient speed control characteristics.[1]

In current educational practice, these types of electrical machines are often taught as separate topics, while their functional and technological interrelationships are not sufficiently emphasized. As a result, although students acquire the ability to perform theoretical calculations, they frequently encounter difficulties when solving engineering design and programming problems in real industrial environments. Such challenges include selecting the most appropriate type of electrical machine for specific operating conditions, evaluating energy efficiency, determining optimal operating modes, and diagnosing potential faults.[2]

This research is aimed at identifying the pedagogical conditions that contribute to the development of students' practical professional competencies in the teaching of the Electrical Machines course and at establishing the scientific and methodological foundations for their effective implementation in educational practice.[6]

Literature Review

Chapman's Electric Machinery Fundamentals (2012) is one of the most widely used textbooks in electrical machine education, integrating theoretical concepts with practical examples and MATLAB-based simulations.[7] Stephen J. Chapman emphasizes the importance of combining analytical approaches with

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computer-aided modeling to enhance students' understanding of electrical machine operation and performance.Similarly, Electric Machinery by A. E. Fitzgerald, Charles Kingsley Jr., and Stephen D. Umans (2014) prioritizes graphical analysis methods in the teaching of synchronous and direct current (DC) machines. [8]

Their approach facilitates a deeper understanding of machine characteristics, operating modes, and performance evaluation through visual interpretation of electrical and mechanical relationships.

Among regional researchers, Slesarev (2019) demonstrated that the use of virtual laboratory environments can improve students' competencies in induction machine studies by approximately 35%. Likewise, Panfilov and Lisitsyn (2020) proved that explaining the operating mechanism of the commutator through animated visualizations significantly enhances students' learning outcomes in DC machine courses.

Research Methods

This study was conducted between 2023 and 2026 at the Department of Energy and Electrical Technology of the Jizzakh Polytechnic Institute using the available laboratory facilities, including the Electrical Machines Laboratory Complex, and involving second- and third-year undergraduate students.

A total of 256 students participated in the experiment. The control group (128 students) was taught using traditional instructional methods, while the experimental group (128 students) was instructed based on a system of pedagogical conditions designed to develop professional competencies. [3]

At each stage of the study, students' competencies in technical calculations, engineering design, practical skills, and analytical thinking were assessed using a 100-point evaluation scale.

The collected data were analyzed to determine the effectiveness of the proposed pedagogical conditions in improving the professional competencies of future electrical engineers.

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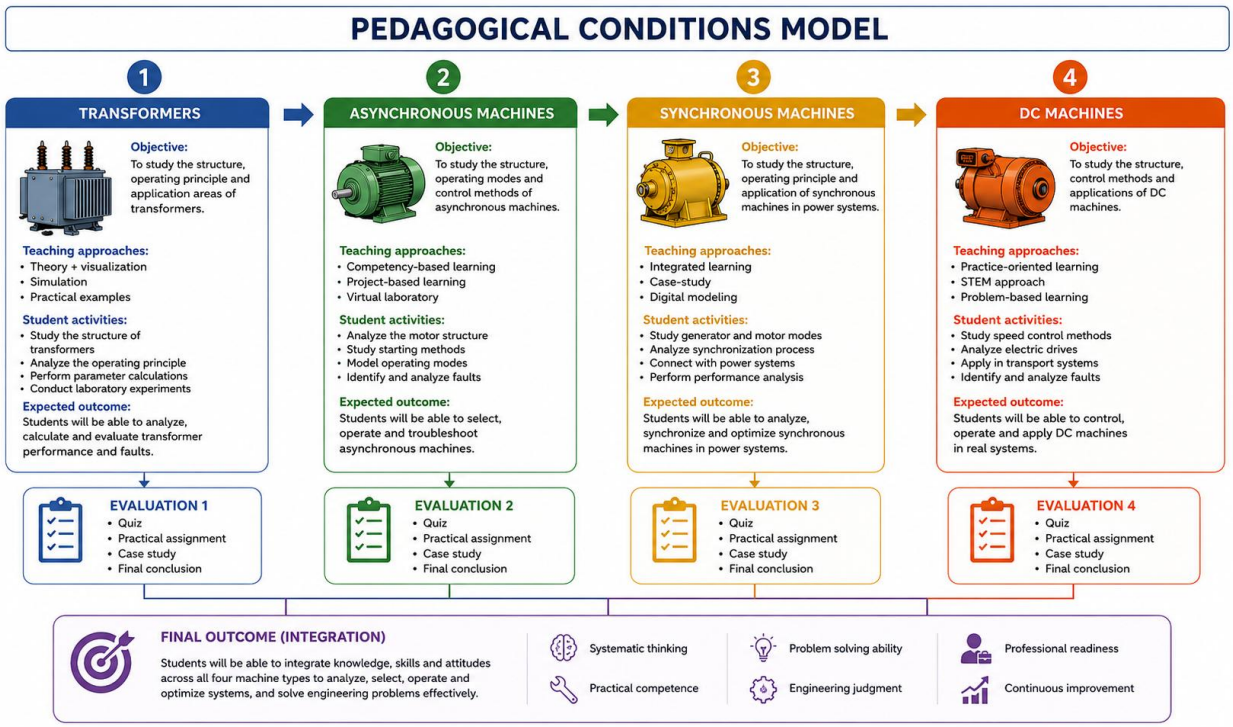

Figure 1. Pedagogical Conditions Model for Teaching Electrical Machines

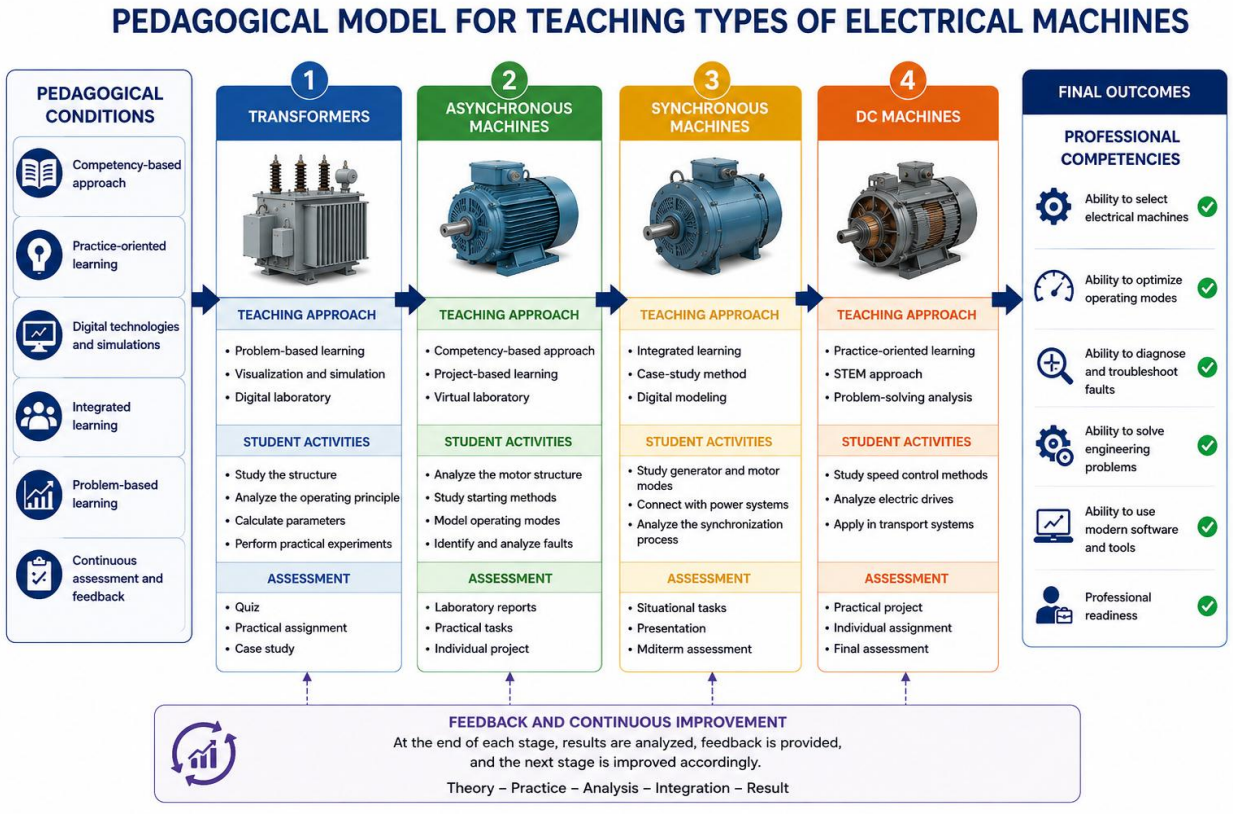

Figure 2. Model of pedagogical approach to types of electric machines

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Research Results and Discussion

The results obtained at each measurement stage across the four instructional modules are presented below. The first graph illustrates the overall progression of the experimental and control groups throughout the study, while the second graph presents the final competency indicators achieved for each type of electrical machine.[4]

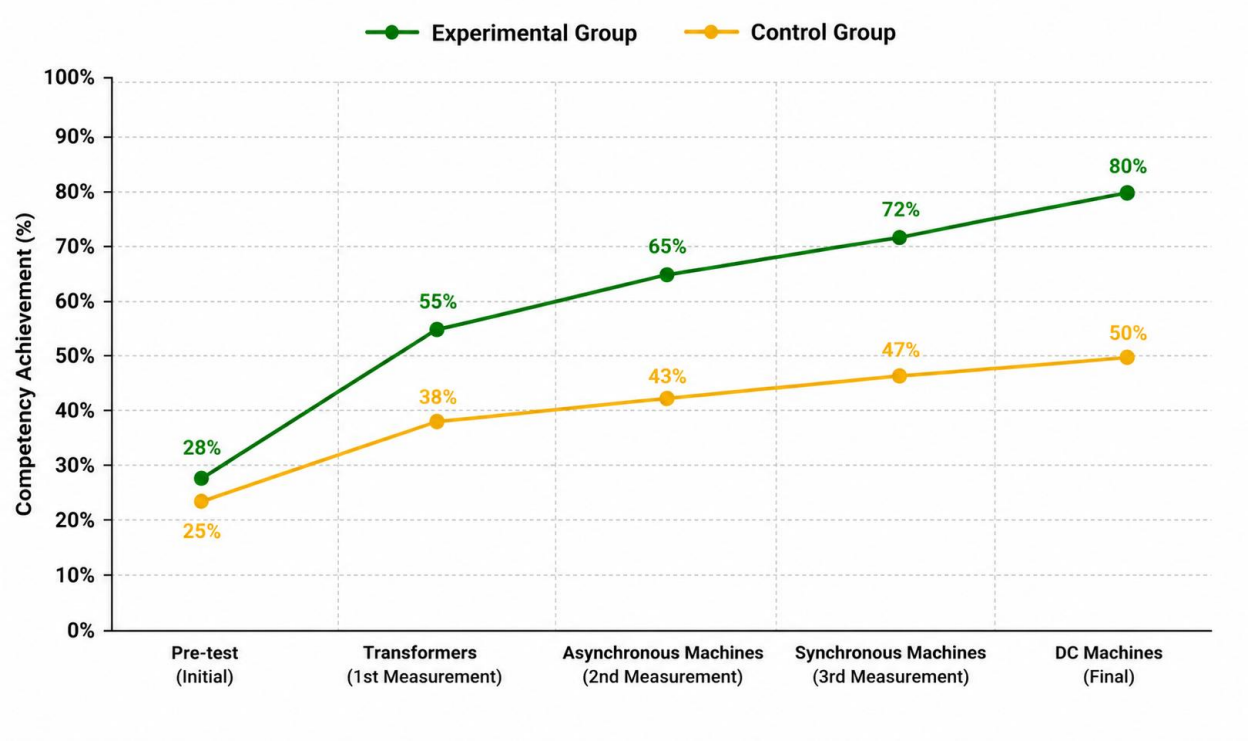

Figure 3. Dynamics of the level of competence in four departments (%)

The most important result is the growth rate of each section: in the experimental group, each new section increased the level of competence by an average of 18 percentage points, while in the control group it increased by 9 percentage points. This difference clearly shows the contribution of the teaching methodology.[5]

Figure 4 The final results of students' competencies by types of electrical machines were compared. The graph shows the indicators of technical calculation, design, practical and technical activity, and professional thinking in the sections of transformers, asynchronous machines, synchronous machines, and AC machines. According to the results, growth dynamics was observed in all types of competencies. In particular, technical calculation competence was 76% in the transformer department, and reached 80% in the AC machines department.

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Design competence increased from 68% to 74%, practical and technical competence from 72% to 78%, and professional thinking from 64% to 71%.[5]

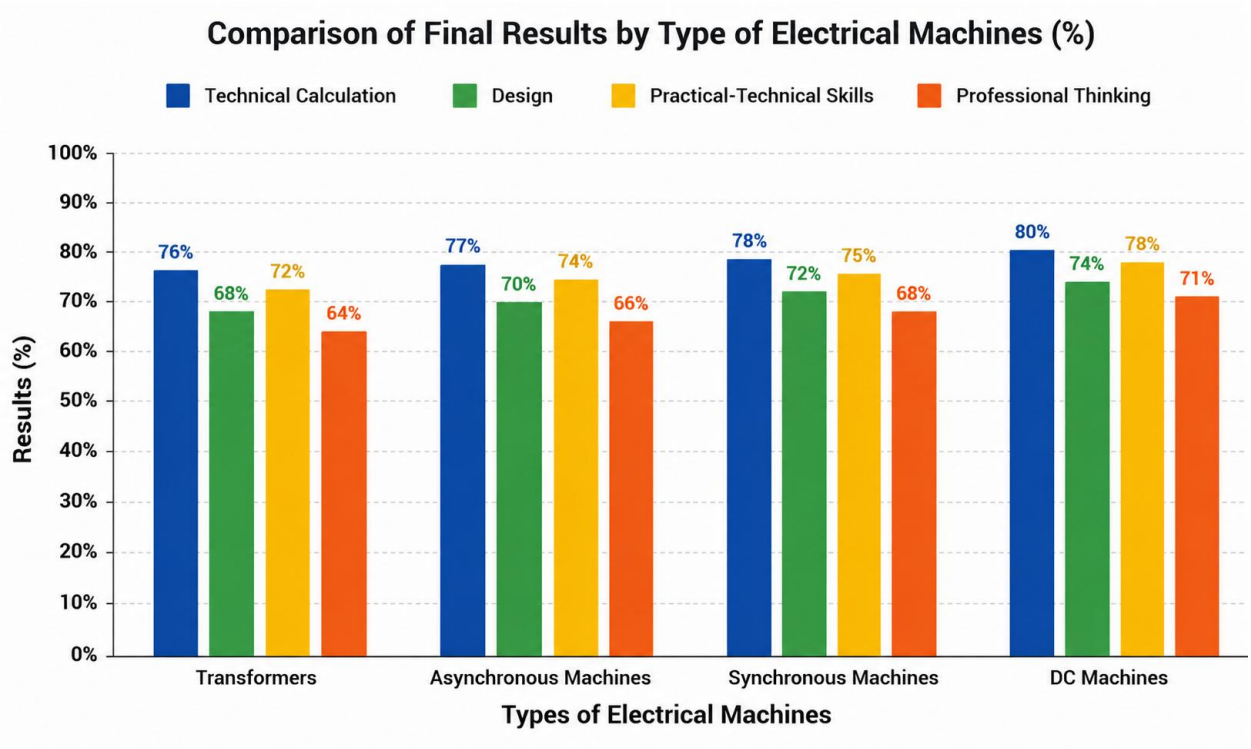

Figure 4. Comparison of final results by type of electric machine

Table 1. Final results by type of electric machine and four competency areas (n=256, p<0.01)

Electric machines	Technical calculation	Design	Practical	Thinking	The experience is average.	Theoretical average	Δ
Transformers	83%	75%	71%	80%	**77%**	51%	**+26%**
Asynchronous machines	82%	74%	70%	83%	**77%**	50%	**+27%**
Synchronous machines	80%	77%	73%	86%	**79%**	49%	**+30%**
DC Machines	85%	79%	76%	84%	**81%**	53%	**+28%**
Overall average	**83%**	**76%**	**73%**	**83%**	**78,5%**	**50,8%**	**+27,8 %**

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Conclusion

The study demonstrated, through an experimental investigation, that the implementation of a pedagogical conditions system across the four modules of the Electrical Machines course—Transformers, Asynchronous Machines, Synchronous Machines, and DC Machines—resulted in an average increase of 27.8 percentage points in students' professional competency levels ($n = 256$, $p < 0.01$). The highest effectiveness was observed in the modules on Synchronous Machines (+30%) and DC Machines (+28%), indicating the significant contribution of the proposed pedagogical approach to the development of professional competencies in electrical engineering education.

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