

# Reflections on the Reform of Teaching Methodology in the "Electrical Machines" Course

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## Abstract

This paper systematically investigates teaching reform strategies to address key challenges in the instruction of "Electrical Machines," including an overly extensive curriculum, low student engagement in practical sessions, lack of innovation, and monolithic teaching methodologies. First, a dual-track teaching model is proposed, combining dynamic visual demonstrations with physical disassembly of real machines—utilizing vector animations to illustrate the formation trajectory of rotating magnetic fields and gradient-colored magnetic flux line cloud maps to visualize magnetic flux distribution patterns. Second, a blended practical training system is implemented, integrating virtual simulations as a preliminary step followed by hands-on experimental validation, thereby establishing a closed-loop integration of theory and practice. Finally, a student-centered interactive teaching approach is developed. Through these comprehensive reforms, the course transitions from abstract theoretical derivations toward engineering-oriented cognition, from passive verification-based lab work toward active inquiry and innovation, and from one-way knowledge transmission toward multidimensional competency development. These transformations significantly deepen students' understanding of electrical machine principles, enhance their learning motivation, and foster innovative capabilities—laying a solid foundation for cultivating innovative electrical engineering talent capable of meeting the demands of China's "Dual Carbon" strategy and intelligent manufacturing initiatives.

## Keywords

Electrical Machines; Teaching Reform; Virtual-Physical Integration; Student-Centered.

## 1. Introduction

As core equipment in modern industries and energy systems, electric machines are widely applied in sectors such as power, transportation, manufacturing, home appliances, and new energy. They not only achieve efficient conversion between electrical and mechanical energy but also play a critical role in intelligent control and green development. In the talent cultivation system for electrical engineering majors, "Electrical Machines" is a comprehensive foundational engineering course that bridges previous and subsequent studies. It systematically integrates fundamental knowledge acquired by students, including circuit analysis, electromagnetic field theory, and engineering mechanics, providing a solid theoretical foundation for advanced courses like motors and drives, power electronics, electrical controls, and new energy power generation. Therefore, this course embodies both a high degree of theoretical depth and practical engineering attributes, emphasizing the organic unity of knowledge dissemination, skill training, and engineering literacy. It holds irreplaceable significance for the professional capability building and career development of electrical engineering students, especially those from general undergraduate and application-oriented universities.

However, the content system of the "Electrical Machines" course is vast, with abstract concepts, complex mathematical derivations, and involves multiple challenging areas such as

electromagnetic induction, magnetic circuit analysis, coordinate transformation, and dynamic modeling. Students commonly report difficulties in understanding and lack of interest in learning, leading to ineffective outcomes with traditional teaching methods characterized by unidirectional knowledge transmission from teacher to student, failing to effectively meet course objectives. In recent years, to improve teaching quality, numerous educators have actively explored paths for teaching reform. For instance, reference [1] reconstructs modular content based on industry-education integration, establishing a diverse teaching and evaluation system encompassing online and offline components, simulation practices, and group collaboration, integrating ideological and professional education to enhance students' overall abilities. Reference [2] proposes a new blended teaching model for "Electrical Machines" by combining virtual and real elements with visualization-driven approaches, merging theoretical simulations with actual measurements. Reference [3], guided by the "Dual Carbon" goals, creates a teaching model featuring virtual-real integration and hierarchical task-driven instruction to enhance students' comprehensive capabilities and support green talent development. Reference [4] restructures outlines, content, teaching methods, and assessments according to new engineering education concepts to comprehensively elevate the quality of teaching "Electrical Machines". Reference [5] integrates knowledge, practice, and teacher-student interaction through diversified teaching to effectively boost student engagement and teaching quality. Reference [6] simplifies motor structure content, builds simplified models, and utilizes VBA technology to dynamically showcase motor principles, reducing learning difficulty and enhancing classroom interaction and teaching effectiveness.

These practices demonstrate that through teaching reforms, it is possible to effectively bridge the gaps between theory and practice, classrooms and industries, and knowledge and capabilities, significantly enhancing the advanced nature, innovativeness, and challenge level of the course.

## 2. Problems in the Teaching of the "Electrical Machines" Course

(1) Theoretical instruction is abstract and complex.

As a core foundational course for electrical engineering and automation majors, "Electrical Machines" has long faced the prominent challenge of "high abstraction and complexity" in its theoretical instruction. This course deeply integrates multidisciplinary knowledge including electromagnetic field theory, circuit analysis, and mechanical dynamics, systematically teaching the structural principles, electromagnetic relationships, and operational characteristics of DC machines, transformers, induction motors, and synchronous motors. However, key content areas such as the formation mechanism of rotating magnetic fields, the spatiotemporal distribution of air-gap flux, the process of electromechanical energy conversion, and dynamic modeling under multiple coordinate systems are behaviors of invisible and intangible physical fields, heavily relying on students' spatial imagination and abstract thinking abilities.

Moreover, the course extensively employs advanced mathematical tools like complex phasors, differential equations, and Fourier series. The lengthy chains of theoretical derivation and complex symbolic systems can easily lead students with weaker foundations into a dilemma where they prioritize calculations over understanding. More critically, the knowledge system of electrical machines is highly coupled and progressive: unclear concepts of magnetic circuits make it difficult to understand core saturation effects, while shaky knowledge of DC machines constrains deeper learning about AC machine characteristics. Once initial foundations have gaps, subsequent content becomes hard to connect. Traditional teaching tends to focus on formulaic derivations rather than engineering relevance, often leading to cognitive disconnection and learning fatigue among students due to the "invisibility, intangibility, and

lack of practical application" nature of the course materials. This results in low classroom engagement, poor knowledge retention, and weakened application skills. Therefore, teaching methods in "Electrical Machines" should start with concretizing abstract concepts, modularizing complex processes, and engineering theoretical knowledge, thereby reducing cognitive load and enhancing students' depth of understanding of the intrinsic mechanisms of electrical machines.

(2) Students exhibit low engagement in practical projects and lack innovation.

Electrical machine experiments involve potential risks such as rotating components, high voltage, and electromagnetic fields. To ensure safety, experimental equipment is mostly configured in fixed setups with strictly defined procedures, leaving students only able to passively follow preset steps without the opportunity to independently adjust parameters or explore operational space. This approach severely diminishes the practicality of experiments, reducing students to mere executors of procedures rather than thinkers.

Secondly, the design of experimental content falls into a "verification trap." Traditional electrical machine experiments mainly focus on basic validation projects, such as "DC generator mechanical characteristic measurement experiments" and "three-phase asynchronous motor start-up characteristic testing experiments," where students merely need to record data according to the steps to complete tasks. Such experiments lack open-ended questions and innovative challenges, failing to guide students to actively investigate core theories like internal electromagnetic processes and torque-speed relationships of motors. They also fail to simulate the complexity and variability involved in real-world motor debugging scenarios.

Moreover, the disconnect between theory and practice is increasingly pronounced. The theoretical aspects of electrical machines are highly abstract, involving dynamic processes such as rotating magnetic fields and electromagnetic induction, while experiments only present static results. Students cannot grasp key mechanisms, such as how a rotating magnetic field drives the rotor, through hands-on operation. The disconnection between experimental content and theoretical teaching leaves students' understanding of electromagnetic principles at a symbolic level, making it difficult to form a complete cognitive chain. Additionally, practical teaching models are monotonous and rigid, with laboratory sessions often adopting a one-way transmission mode of "teacher demonstration-student operation," which involves minimal interaction between teachers and students. Students lack opportunities for questioning, designing, and improving experiments. Experimental evaluations focus solely on operational standards and data accuracy, neglecting the cultivation of higher-order abilities such as innovative thinking and problem-solving skills, thus failing to reflect the innovation-oriented practice advocated by the "new engineering" education philosophy.

These factors interweave, leading to a vicious cycle of content rigidity and cognitive disconnection in electrical machine experiments. Not only does this constrain students' deep understanding of abstract electromagnetic theories, but it also hinders the development of innovative thinking and engineering practice capabilities, making it difficult to achieve the goal of cultivating application-oriented talents.

(3) Teaching methods are monotonous

Currently, the teaching of the "Electrical Machines" course still predominantly relies on a teacher-centered, one-way lecture format, using multimedia slides and blackboard writing as the primary instructional media. This approach is highly monotonous and lacks interactivity. The traditional "lecture-through" method offers minimal opportunities for meaningful classroom interaction or cognitive engagement, with insufficient design for stimulating critical thinking.

Moreover, communication channels between instructors and students are limited, making it difficult for teachers to promptly gauge students' depth of understanding—or

misconceptions—regarding core concepts such as electromagnetic relationships in machines and winding distributions. As a result, instructors cannot dynamically adjust teaching pace or emphasize key content based on real-time learning needs.

Furthermore, the absence of an effective feedback mechanism leads to a disconnect between instructional content and students' actual learning requirements, causing delays in pedagogical refinement. Consequently, students' grasp of motor principles remains superficial, their engineering application abilities are inadequately developed, and overall teaching quality fails to achieve meaningful improvement.

### **3. Suggestions and Recommendations for Reforming the "Electrical Machines" Course to Meet the Needs of Application-Oriented Talent Development**

#### **(1) Materializing abstract theories**

In the "Electrical Machines" course, the abstract and invisible nature of electromagnetic processes has long been a core bottleneck limiting teaching effectiveness. To overcome this challenge, a dual-track teaching model centered on "dynamic visualization demonstrations + physical disassembly structures" is designed. By transforming invisible electromagnetic processes into intuitive visual representations and combining abstract physical concepts with tangible real-world understanding, this approach significantly enhances students' depth of understanding and learning efficiency.

For the explanation of theoretical knowledge, first, three-dimensional animation technology is utilized to dynamically showcase the spatial and temporal distribution patterns of internal magnetic fields in motors. For instance, vector animations can be used to present the trajectory formation of a rotating magnetic field synthesized from three-phase currents in real-time, converting the abstract concept of synchronous speed into a visually observable rotational motion. Second, simulation software is employed to generate gradient-colored magnetic flux line cloud diagrams, providing an intuitive display of air-gap flux density distribution characteristics and saturation effects. Finally, through interactive courseware design, students are allowed to adjust power source parameters in real-time and observe the dynamic responses of magnetic field shapes and output characteristics, fostering parameter sensitivity and systems thinking. Meanwhile, to deepen students' learning about motor structures, dissected motor models and key components (such as stator windings and rotor structures) are showcased, rendering abstract content like motor structures and magnetic fields visible and vivid. This helps students establish spatial structure cognition and enables multi-dimensional participation in the teaching process.

This method shifts the focus from unidirectional teacher-centered instruction to student-driven construction and moves from abstract theoretical derivations to concrete engineering cognition. Embedding knowledge points such as electromagnetic field theory and circuit analysis into visualized contexts significantly reduces cognitive burdens for students. Building theoretical knowledge step-by-step and hierarchically aids students in better comprehending abstract theories, effectively boosting their learning enthusiasm and innovative thinking.

#### **(2) Strengthening the Practical Component of the Course**

To address the low student engagement and lack of innovation in the experimental teaching of "Electrical Machines," it is essential to develop an integrated virtual-physical, competency-oriented innovative practical training system that shifts students from "passive operation" to "active inquiry."

First, establish a hybrid experimental model combining virtual simulation with physical validation. A virtual motor experimentation platform can be built using MATLAB/Simulink,

allowing students to freely adjust parameters in a safe environment, observe dynamic changes in internal electromagnetic fields, and analyze performance differences under various operating conditions. Through virtual experiments, students gain deeper insight into abstract processes—such as the formation of rotating magnetic fields and the generation of electromagnetic torque—thereby establishing a solid theoretical foundation for subsequent hands-on physical experiments.

Second, innovate pedagogical approaches by implementing a tiered, progressive practical teaching framework. Experiments are organized into three levels: familiarization with equipment operation, analysis of motor performance, and solving real-world engineering problems. Students can choose their level of engagement based on their individual capabilities, while instructors transition from demonstrators to facilitators who pose questions and stimulate active thinking.

Third, implement a diversified assessment system that emphasizes innovative thinking and problem-solving abilities. Evaluation criteria shift toward dimensions such as “experimental design quality,” “depth of problem analysis,” and “contribution of innovative ideas.” Digital learning platforms can record students’ experimental process data and generate personalized competency development reports, enabling precision teaching.

Finally, strengthen university–industry collaboration by integrating authentic engineering case studies. This exposes students to real-world motor testing procedures and helps them understand relevant industry standards and practices.

Through these measures, the experimental teaching of "Electrical Machines" will evolve from rigid, verification-based exercises into a dynamic, safe, and innovation-driven learning experience. This fosters deep integration of theory and practice, cultivating innovative electrical machine engineers who are both theoretically knowledgeable and practically skilled—providing strong support for the “New Engineering Education” initiative. Moreover, students will transition from passively receiving theoretical knowledge to actively solving engineering challenges, achieving a qualitative leap from theoretical understanding to innovative practical competence, and truly transforming their knowledge of electrical machines into engineering capabilities for tackling complex real-world motor-related problems.

(3) Promote a closed-loop teaching approach that integrates theory and practice.

Theoretical instruction and practical teaching are mutually reinforcing—especially in a course like "Electrical Machines," where practical components should be designed to deepen students’ understanding of theoretical concepts. Taking DC motors as an example, after students learn about motor structure, air-gap magnetic fields, and speed control methods in theory, the subsequent laboratory sessions should specifically target these topics through hands-on experiments. This allows students to directly observe the operational principles of DC motors, thereby solidifying and enriching their conceptual grasp of the theory.

Therefore, for engineering disciplines, courses with strong engineering relevance should include corresponding experimental components that provide feedback to—and reinforce—theoretical instruction. Moreover, the design of these experiments should align closely with abstract or particularly important practical aspects covered in the theoretical content, ensuring better achievement of instructional objectives.

Through such a closed-loop teaching approach that integrates theory and practice, students can develop a deeper understanding of theoretical concepts and gain clearer insight into the operational procedures of real-world engineering projects.

(4) Develop a student-centered interactive teaching model.

Current teaching practices still rely predominantly on one-way lectures by instructors. Although the combination of multimedia and blackboard writing has improved the efficiency of information delivery, it suffers from a lack of teacher–student interaction. Instructors struggle

to gauge students' real-time cognitive states and are thus unable to dynamically adjust their teaching strategies. This "transmission-based" approach positions students as passive recipients of knowledge, depriving them of opportunities to actively construct understanding, which ultimately leads to low classroom engagement and poor learning outcomes.

Given the inherent limitations of in-class learning, instruction should shift toward a student-centered blended learning model. Before class, short instructional videos and preparatory assignments can be distributed to students; during class, the focus can then shift to discussing challenging concepts and addressing misconceptions. Additionally, online resources—such as MOOCs (Massive Open Online Courses)—can serve as pre-course materials, enabling students to gain preliminary exposure and enter formal classes with greater ease and readiness.

Furthermore, platforms like Chaoxing Learning App (Xuexitong) can support hybrid online-offline instruction. Instructors can upload lecture slides and specify required pre-class reading or viewing materials, accompanied by quizzes to assess students' preparation. This not only promotes more effective in-class teaching but also fosters students' self-directed learning habits. By identifying questions through pre-class study, students come to class with curiosity and purpose, which enhances their motivation and engagement. Such an approach further stimulates critical thinking and creativity, helping students develop strong, independent learning habits.

Establishing a "student-centered" interactive teaching model hinges on igniting students' intrinsic motivation to learn and guiding them to actively participate, think deeply, and collaboratively explore. Ultimately, this facilitates a fundamental shift—from "passive reception" to "active knowledge construction"—ensuring that teaching truly serves students' holistic development.

#### 4. Conclusion

As a pivotal foundational course that bridges earlier and advanced studies in the Electrical Engineering and Automation program, the "Electrical Machines" course plays a crucial role in shaping students' engineering practice capabilities and innovative thinking. The quality of its instruction directly impacts the development of these essential competencies. This paper addresses three long-standing challenges in teaching Electrical Machines—namely, the abstract and difficult-to-grasp theoretical content, low student engagement in practical activities, and monotonous teaching methodologies—and proposes a new framework for pedagogical reform aimed at shifting the focus from knowledge transmission to capability development.

To tackle these issues, this paper outlines four key pathways for teaching reform:

First, a dual-track instructional model combining dynamic visual demonstrations with physical disassembly of motor structures is introduced. Abstract electromagnetic processes are rendered intuitive through visual representations—for example, vector animations illustrate the formation trajectory of rotating magnetic fields, while gradient-colored magnetic flux line cloud maps reveal flux distribution patterns and saturation effects.

Second, an integrated virtual-physical practical training system is implemented, featuring virtual simulation followed by physical experimental validation. A virtual motor experimentation platform built on MATLAB/Simulink enables students to freely adjust parameters and observe dynamic changes in electromagnetic fields in a safe environment, thereby establishing a solid theoretical foundation before engaging in hands-on lab work.

Third, a closed-loop teaching approach linking theory and practice is established. Experimental content is closely aligned with theoretical instruction—for instance, after studying DC motor theory (covering structure, air-gap magnetic fields, and speed control), students perform corresponding experiments to directly observe motor operation, deepening their conceptual understanding.

These strategies collectively address core teaching challenges in the Electrical Machines course: they enhance the efficiency of theoretical instruction, increase student autonomy in practical learning, and create effective feedback loops from practice back to theory—thereby laying a strong foundation for students' future professional engineering roles.

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