ISSN 2522-6398 Vol. 8, Issue 8: 48-53, DOI: 10.25236/FER.2025.080809

An Innovative Study of AI-Empowered and Symmetric Beauty-Driven Teaching of Engineering Electromagnetic Fields Based on OBE

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Abstract: *Based on the Outcome-Based Education (OBE) concept, this study constructs a new teaching paradigm of integrating symmetric beauty into engineering electromagnetic field courses with AI empowerment. By analyzing the symmetry nature of electromagnetic theory, a three-level achievement goal of "knowledge - ability – quality" is established. Core knowledge is deeply coupled with symmetry analysis, and a thinking training chain of "symmetry conservation - breaking analysis - reconstruction innovation" is innovatively designed. With the application of AI technology, symmetry cognition diagnosis, virtual simulation, and innovative optimization are realized, which deepens students' understanding of complex theories and improves compliance rate of symmetry modelling ability for engineering problems. The research provides a teaching reform path of "enlightening truth through beauty and AI empowerment" for engineering education, highlighting the paradigm innovation value of scientific aesthetics.*

Keywords: *Symmetrical Aesthetics, Engineering Electromagnetic Field, AI Empowerment, Outcome-Based Education, Teaching Paradigm Reconstruction*

1. Introduction

As a core course in engineering, the abstract nature of engineering electromagnetic field leads students to face three major predicaments: difficulty in understanding field distribution, difficulty in associating laws, and difficulty in engineering transfer. Traditional teaching emphasizes formula derivation over thinking cultivation and lacks a systematic design that reveres teaching from engineering achievements. Outcome-based Education (OBE) [1,2] emphasizes "student outcome-based education" and provides methodological guidance for breaking through bottlenecks.

Symmetry, as an aesthetic expression of nature's fundamental laws, carries profound physical connotations and methodological value in electromagnetic theory. From Gauss' law to the spatiotemporal covariance of Maxwell's equations, symmetry runs through the knowledge system and serves as a "thinking tool" for simplifying problems and a "cognitive bridge" connecting theory and practice. Zhenning Yang pointed out that "symmetry governs interaction", but existing research has not yet established a symmetrical aesthetics teaching transformation mechanism based on OBE, lacking systematic exploration of "goal – strategy – evaluation". Against this background, this study integrates symmetric beauty with OBE concept, and combines AI technology to construct a new teaching system to achieve a transformation of paradigm from knowledge imparting to ability cultivation.

AI technology offers the possibility of empowering symmetric beauty teaching. Its data analysis, virtual simulation and intelligent decision-making capabilities can solve problems such as abstract symmetry cognition and inefficient thinking training, forming an innovative paradigm of "AI-empowered symmetric beauty teaching".

2. Multi-dimensional Outcome-Oriented Representations of Symmetric Beauty in Engineering Electromagnetic Field with AI Empowerment

2.1 Symmetry of Physical Laws: AI-Driven Theory - Engineering Transformation

The duality principle of Maxwell's equations and gauge symmetry constitute the mathematical cornerstone of electromagnetic theory. The curl equations of electric and magnetic fields in the equations

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form time-space symmetric coupling, presenting formal unity under free-space conditions, providing a logical starting point for the derivation of electromagnetic wave characteristics.

The AI-empowered intelligent analysis platform can deconstruct the symmetry of the equations: converting symmetry descriptions into visual dual graph through natural language processing, and predicting field distributions under different symmetric conditions using deep learning [3]. For instance, when analyzing the symmetrical structure of a transformer core, AI simulates the zero-sequence magnetic flux suppression effect in real time, helping students establish an intuitive connection between "theoretical cognition - engineering modelling", and achieve the ability goal of "predicting field distribution using symmetry".

2.2 Geometric Structure Symmetry: AI-Assisted Model Simplification and Performance Optimization

Geometric symmetry is the core prior condition for engineering electromagnetic field modelling. Spherical symmetry and cylindrical symmetry structures can reduce the dimension of three-dimensional field equations and improve the solution efficiency. For instance, the symmetry of a uniformly charged sphere makes the electric field only a radial function. Using Gauss' law reduces calculation by 90% compared with Poisson's equation.

The computer vision technology of AI can automatically identify the symmetry of geometric structures, analyze the symmetry operation groups and recommend solution methods. In electromagnetic shielding design, the AI platform generates symmetrical structure schemes based on shielding effectiveness. Finite element simulation comparisons show that the calculation of symmetrical structures is reduced by 70%, while meeting engineering indicators, reflecting the practical value of symmetry in performance optimization.

2.3 Mathematical Expression Symmetry: AI-Enhanced Operator Duality and Conceptual Construction

Within the mathematical framework of engineering electromagnetic fields, the duality exhibited by gradient - curl operators and scalar - vector potential forms a logical connection of cognitive framework of the "source - potential - field". Helmholtz's theorem provides a rigorous mathematical basis for field decomposition symmetry, aiding students in understanding the fundamental distinctions between electrostatic and steady magnetic fields.

AI-empowered tools for analyzing mathematical symmetry can automatically identify symmetry operators in equations and generate interpretations of their physical significance and engineering cases. In phased array antenna design, AI system employs symmetry to simplify radiation pattern calculation, optimizes element placement through reinforcement learning, and achieves low sidelobe emissions. This process cultivates students' higher-order thinking of "formal symmetry - physical correspondence - method migration".

3. The Achievement Target System of AI-Empowered Symmetrical Aesthetics Teaching Based on OBE

3.1 Knowledge Level: AI-Constructed Cognition Map of Symmetry

Based on OBE knowledge objectives, a three-layer knowledge network centered on the principle of symmetry is constructed by using knowledge graph and neural network technology: the basic layer (group theory, vector analysis), the method layer (symmetric reduction method, breaking analysis), and the application layer (transformer design, antenna optimization).

The AI system generates personalized learning paths according to students' cognitive levels. When students learn Gauss' law, the system recommends symmetric types, field distribution characteristics, and solution tools based on students' previous performance, forming a learning process of "symmetry analysis - equation reduction - boundary condition simplification", which enhances the ability of knowledge reconstruction.

3.2 Ability Level: Training System for Three-Dimensional Symmetric Thinking

Based on OBE ability objective, a thinking training chain of "conservation - breaking - reconstruction"

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is designed, and intelligent training is achieved with the help of AI [5].

3.2.1 Symmetry Conservation Thinking: AI-Assisted Forward Analysis

The AI provides an interactive training platform where students analyze the symmetry of geometric structures in a virtual environment. The system displays in real time the impact of symmetrical operations on field distribution through computer graphics and provides feedback guidance through natural language processing. For example, when analyzing spherical symmetric structures, the system prompts to verify the non-zero property of the field components. The positive thinking of "structure symmetry - field distribution symmetry - equation reduction" through simulation visualization, achieving an accuracy rate of 90% for the identification of symmetric types.

3.2.2 Symmetry Breaking Thinking: AI-Driven Reverse Modelling

The AI symmetry breaking analysis platform automatically identifies the breaking factors in engineering models and quantifies their impacts. Students input asymmetric parameters (such as the eccentricity of an eccentric cable), and the system calculates the field distortion coefficients based on deep learning to generate a correction scheme. For example, when the eccentricity is 5%, the system shows that the non-uniformity of the field strength increases by 20%, achieving a breaking impact quantification error $\leq 5\%$, and helping students master the reverse thinking of "understanding deviations based on symmetrical benchmark".

3.2.3 Symmetry Reconstruction Thinking: AI-Assisted Innovative Design

The AI innovation platform integrates symmetrical transformation and equivalent modelling tools to support engineering innovative design. In the design of metamaterial absorbers, students explore symmetry breaking strategies through AI, symmetrically utilize Generative Adversarial Networks (GAN) [4] to generate design schemes, optimize parameters through reinforcement learning, and ultimately achieve a 50% increase in absorption bandwidth. This process cultivates students' ability of symmetry reconstruction.

3.3 Accomplishment Level: AI-Promoted Engineering Aesthetics Integration

OBE accomplishment objective emphasizes the engineering thinking of "pursuing optimal solutions under constraints". AI assists students in understanding the fit between symmetric beauty and engineering design.

▪ Conciseness: AI optimization algorithm searches for the optimal parameters of symmetrical structures, achieving dual optimization of computational efficiency and material utilization in electromagnetic shielding.

▪ Balance: AI simulation demonstrates the effect of symmetrical arrangement of three-phase transmission lines in reducing zero-sequence impedance by 35%.

▪ Reliability: AI simulation comparison with multi-physics field shows that the uniformity of current distribution under symmetrical grounding devices improves by 60%.

Through AI case teaching, students establish the transformation ability of "scientific symmetry - engineering practicability" and form design accomplishments that balance aesthetic principles and engineering constraints.

4. Construction of an OBE Teaching System Driven by AI-Empowered Symmetric Beauty

4.1 AI Reconstruction of Teaching Content: Outcome-Oriented Knowledge Organization

Following the OBE reverse design principle, AI is utilized to reorganize teaching content.

4.1.1 AI cognitive modelling of symmetric principles

Teaching modules based on deep learning are developed to deconstruct the principle of symmetry into physical, geometric, and mathematical dimensions. For instance, in the teaching Maxwell's equations, AI displays spatiotemporal symmetry through tensor forms and generative animations, and adaptively adjusts the depth of explanation according to student feedback to achieve the goal of "analyzing field propagation using symmetry".

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4.1.2 AI outcome mapping of engineering cases

By constructing a case library based on the knowledge graph, AI automatically recommends cases according to the teaching content (such as the simulation data that the symmetrical structure of the transformer reduces the eddy current loss by 45%), guiding students to establish the mapping of "symmetry element - design variable - performance index".

4.1.3 AI dynamic association of knowledge graphs

Constructing dynamic knowledge graphs by using graph neural networks to correlate "theory - method – application" with symmetry as a node. For instance, when solving "antenna optimization" problems, AI automatically invokes the knowledge chain of "geometric symmetry - radiation symmetry - optimization algorithm" and provides tool support.

4.2 AI Innovation of Teaching Methods: Intelligent Teaching Strategies

By integrating OBE and cognitive science theories, AI-empowered teaching methods are designed.

4.2.1 AI dynamic association of knowledge graphs

An AI-driven dual knowledge matrix platform is constructed, which automatically generates comparison graphs of "concept - law - method" between electric and magnetic fields, and provides personalized suggestions for students' weaknesses. For instance, in the teaching of constant magnetic field, AI intelligently adjusts the explanation focus of dual knowledge based on students' mastery of electrostatic fields to cultivate the ability of knowledge transfer.

4.2.2 AI upgrading of visual construction teaching method

With the help of AI 3D visualization technology, an immersive environment of "symmetrical structure - field distribution - performance index" is built. When students interact, AI generates the field distribution simulations (e.g., electric field cloud diagrams of a charged sphere), labels symmetry and other quantitative indicators, achieving cognitive upgrading from "perceptual aesthetics" to "rational analysis".

4.2.3 AI empowerment of Problem-Based Learning (PBL) teaching

The three-level inquiry task for AI-assisted PBL teaching is designed.

▪ Basic task: The AI experiment platform verifies the symmetry of the electric field distribution of a spherical capacitor and automatically compares the accuracy of analytical and numerical methods.

▪ Advanced task: The AI design platform offers suggestions for optimizing the electrode layout of electromagnetic flow sensors with symmetrical structures.

▪ Innovative task: The AI innovation platform uses generative AI to propose symmetrical structural design schemes for metamaterial and verify them.

4.3 AI Empowerment of Practical Teaching: Cultivation of Intelligent Ability

4.3.1 AI verification of experimental teaching

After the AI experimental platform was developed, a correlation experiment of "symmetry - performance" was designed.

▪ Basic experiment: AI automatically analyzes the distribution of the equipotential line of symmetrical electrodes, assisting students in establishing the association of "geometric symmetry - field distribution".

▪ Comprehensive experiment: AI simulation compares the resonance frequencies of square and rectangular cavities, and calculates the influence of symmetry on modal degeneracy.

▪ Innovative experiment: AI optimization algorithm assists in the design of units with metasurface symmetry to predict electromagnetic characteristics.

4.3.2 AI creation of course design

The AI-assisted course design platform focuses on "symmetrical optimization". For instance, in the design of electromagnetic shielding devices, students input constraint conditions, and AI generates symmetrical multi-cavity schemes and optimizes material usage. In antenna array synthesis, AI utilizes

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symmetry to simplify calculations, and optimizes element spacing.

4.3.3 AI innovation of graduation design

Three types of topics are set up in the AI-supported graduation design system.

▪ Theoretical application category: AI simulation analyzes the coupling characteristics of symmetrical coils of wireless charging systems for electric vehicle.

▪ Technical innovation: AI generative models explore the design of absorbers with symmetry breaking metamaterial.

▪ Engineering design: AI plans the electromagnetic compatibility test platform with multi-antenna symmetrical layout.

5. Evaluation of Teaching Outcome and Innovative Value

5.1 Outcome-Oriented Intelligent Evaluation System

The AI-driven three-dimensional evaluation indexes are established.

▪ Knowledge achievement: The AI assessment system analyzes students' mastery of symmetrical knowledge, and the accuracy rate increases from 58% in traditional teaching to 92%.

▪ Ability compliance: The AI evaluation platform detects the accuracy rate of students' application of symmetric reduction methods, which increases from 41% to 78%.

▪ Accomplishment formation: AI analyzes the proportion of symmetrical innovative schemes in graduation designs, which increases from 15% to 53%.

5.2 Innovation Value

Centering on the three dimensions of theory, method and practice, it showcases the breakthrough progress and unique value achieved by the project in related fields.

▪ Theoretical innovation: Constructing a theoretical model of "AI empowerment - symmetric beauty - outcome goals" to prove the dual value of scientific aesthetics as a cognitive tool and methodology in engineering education.

▪ Method innovation: Establishing a thinking training chain of "AI empowerment-conservation-breaking-reconstruction" to realize the transformation from knowledge transfer to intelligent thinking construction.

▪ Practical innovation: Establishing a teaching system that integrates OBE and AI, the practice of many colleges and universities has shown that the speed of students' analysis of symmetry problems has increased by 60%, and the application rate of symmetry in engineering modelling has increased from 29% to 76%.

6. Conclusions and Prospect

This study constructs a new teaching system for engineering electromagnetic fields driven by symmetric beauty with AI empowerment. Through the integration of OBE concept and AI technology, it realizes the transformation from "Knowledge-oriented" to "Outcome-oriented". Teaching practice shows that this model improves students' symmetry cognition and engineering innovation ability, and provides an effective path for cultivating innovative engineering talents.

Future research can explore the application of generative AI in expression of symmetry principles, develop a multi-modal immersive teaching platforms with symmetric beauty, deepen the role of AI in mechanism discovery of symmetry breaking and reconstruction optimization, and promote the development of engineering education to the higher level of "enlightening truth through beauty and AI empowerment".

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