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Exploring new pathways for integrating ideological and political education into research-oriented teaching from the perspective of human-machine intelligence: a case study of electromagnetic field and wave related courses

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Abstract. Addressing the dual challenges of the "awkward integration" of Ideological and Political Education (IPE) into curricula and the "insufficient depth of inquiry" in Research-Oriented Teaching (ROT), this paper explores a new pathway for teaching reform from the perspective of human-machine intelligence integration, using electromagnetic fields and waves related courses as a case study. This research constructs a teaching model centered on "inquiry as the main line, IPE as the core, and intelligence as the enabler." Specifically, it first utilizes artificial intelligence technologies like data mining and scenario generation to design authentic project scenarios imbued with sentiments of national identity and challenges of engineering ethics, allowing IPE elements to naturally become the starting point of inquiry activities. While students engage in independent inquiry using tools like HFSS/CST, an AI learning companion is introduced. Its function extends beyond assisting with technical simulations; through strategic questioning, prompts, and resource recommendations, it guides students to simultaneously consider the social value and ethical boundaries of their technical solutions, thereby achieving a deep integration of knowledge construction and value guidance. Finally, teachers and students can leverage AI to conduct multi-dimensional analysis of the inquiry process and outcomes, enabling data-driven teaching efficacy evaluation and value-oriented iterative optimization of solutions. This study aims to establish a spiral learning loop of "scenario triggering – intelligence-enhanced inquiry – reflection and internalization," effectively promoting the synergistic development of students' professional competence and ideological-political literacy.

Keywords: curriculum ideological and political education, research-oriented teaching, human-machine collaboration/collaboration, teaching model

1. Introduction

All images in the main text must ensure sufficient clarity to clearly display the content within the images. All formulas, tables, and program codes in the article must be in an editable format and should not be presented as photos or screenshots. All references must be cited in the main text.

Electromagnetic fields and waves related courses (e.g., "Electromagnetic Fields and Electromagnetic Waves," "Microwave Technology and Antennas") are core foundational courses in electronic information majors, characterized by a rigorous theoretical system, complex mathematical tools, and a combination of high abstraction and broad applicability [1, 2]. For a long time, these courses have commonly faced teaching challenges such as "difficulty in conceptual understanding, blurry physical imagery, and lack of student interest." Traditional lecture-based models struggle to effectively support students' deep understanding of core theories and their engineering transfer [3]. Simultaneously, in the context of comprehensively promoting IPE, how to achieve the natural integration of professional knowledge and value guidance, avoiding the "awkward implantation" of IPE content and the "perfunctory integration" into the teaching process, has become an urgent problem to solve in teaching reform [4-6].

In existing practices, ROT is regarded as an important approach to enhancing students' inquiry skills and innovative literacy. However, in electromagnetic fields and waves related courses, its advancement faces the bottleneck of "insufficient inquiry depth" [7]. The reasons lie, on one hand, in the difficulty of directly observing physical phenomena like fields and waves, lacking effective visualization and interaction methods; on the other hand, traditional teaching carriers find it hard to support the immediate feedback and contextual support required for higher-order cognitive tasks, making it difficult for students to establish effective connections between abstract concepts and engineering practice.

With the deep integration of information technology and education, "human-machine collaboration" provides a new perspective and pathway to address the above dilemmas [8, 9]. In this study, "human-machine collaboration" specifically refers to the organic whole formed by teachers, students, and professional electromagnetic simulation tools (e.g., HFSS, CST, ADS). These tools can achieve precise simulation and dynamic visualization of complex electromagnetic processes, transforming invisible fields and waves into observable, interactive, and iterable numerical and graphical results, thereby constructing a "perceivable, intervenable, and verifiable" cognitive environment for students. Based on this, this paper, grounded in the philosophy of "teacher-led, technology-enabled" and using electromagnetic fields and waves related courses as the vehicle, explores a new pathway for integrating IPE into ROT. By constructing a trinity teaching model of "human-machine collaboration, IPE integration throughout, inquiry-driven," it aims to achieve the organic unity of professional knowledge transmission, comprehensive ability cultivation, and value shaping, providing a practical paradigm for reference in the reform of electronic information engineering education.

2. Results

2.1. The connotation of the new "Human-Machine Collaboration, IPE Integration, Inquiry-Driven" teaching model

This is a trinity teaching model of "Human-Machine Collaboration, IPE Integration, Inquiry-Driven." This model is not a simple superposition of the three, but rather uses "Inquiry-Driven" as the engine, "Human-Machine Collaboration" as the dual wings, and "IPE Integration" as the navigational beacon, jointly guiding students to achieve the synergistic development of knowledge, ability, and literacy, ultimately constructing an organically integrated ecosystem.

Human-Machine Collaboration: Empowering the Reconstruction of the Teaching Process. In this model, the relationship between "human" (teachers and students) and "machine" (intelligent simulation platforms, computational tools, virtual experiment environments) is redefined. The machine is no longer just an auxiliary tool but becomes a "cognitive partner" that handles massive data, enables complex system simulations, and provides immersive experiences, liberating teachers and students from tedious calculations and abstract imagination. The teacher's role shifts from knowledge transmitter to learning scenario designer, guide of the inquiry process, and igniter of value inspiration; students change from passive recipients to active inquirers and meaning constructors. The core of human-machine collaboration lies in complementary advantages, using "machine intelligence" to enhance "human intelligence," providing technical feasibility for high-level inquiry and deep IPE integration.

IPE Integration: The Organic Blending of Value Guidance. "Integration" means that IPE elements are not external "plug-ins" but the "soul" inherent in the fabric of the course. It requires dissolving sentiments of national identity, scientific spirit, engineering ethics, craftsmanship spirit, etc., into the entire teaching process, like salt dissolving in water. In electromagnetic fields and waves related courses, this means: permeating materialist dialectics and scientific aesthetic sense at the origin of knowledge (e.g., the unity and harmonious beauty of Maxwell's equations); stimulating national pride and the mission of serving the country through science and technology in technical applications (e.g., 5G, BeiDou); cultivating engineering ethics and social responsibility in problem-solving (e.g., antenna design, electromagnetic compatibility); and honing the rigorous, truth-seeking, and excellence-pursuing craftsmanship spirit through repeated iterations and optimizations.

Inquiry-Driven: The Fundamental Shift in Learning Approach. This model uses authentic, valuable complex problems or projects as the starting point for learning. The entire teaching activity is pulled by the main thread of "inquiry." Students actively construct knowledge and develop abilities through the processes of asking questions, designing solutions, simulating verification, analyzing results, and collaborative communication. Inquiry-driven provides the application scenario for "human-machine collaboration" and creates the natural context for "IPE integration." In tackling the challenges of solving real engineering problems, students develop a deeper emotional identification and rational understanding of the values embedded within them.

2.2. Case analysis and effectiveness: taking the "Electromagnetic Wave Radiation" unit as an example

Using the comprehensive unit "Microstrip Antenna Design" in the "Microwave Technology and Antennas" course as an example, the implementation of this model can be divided into three interlocking and progressively advancing stages:

2.2.1. Project background and integrated scenario creation

The project originates from a simplified real engineering scenario: "Design a microstrip antenna operating in the 2.4GHz ISM band for a smart city Internet of Things (IoT) sensor node, requiring low profile, easy conformality, with return loss S11 <

-15dB, and gain > 3dBi."

In the classroom introduction, the teacher used CST Studio Suite to pre-simulate a poorly performing initial antenna model (S11 ≈ -8dB), displaying its weak radiation field pattern and non-compliant S-parameter curve in real-time. This transformed the abstract design specifications into an intuitive "fault" image for students, effectively stimulating their inquiry interest. Building on this, the teacher guided students to consider the core significance of smart cities within China's "New Infrastructure" strategy and the key role of IoT technology in areas like smart homes and industrial IoT for people's livelihood and industrial upgrading. Thus, the specific task of antenna design was closely linked to the era's mission of "building a strong country through technology" and "breaking through 'chokepoint' technologies," enhancing students' sense of intrinsic responsibility and commitment, and solidly launching the project inquiry with value guidance.

2.2.2. Three-phase teaching implementation process and points of human-machine-IPE integration

Phase 1: Collaborative Design and Simulation Inquiry. Students, in project groups of 3-4, applied transmission line theory to calculate the initial patch dimensions and focused on designing the impedance matching network. Human-machine collaboration unfolded deeply here: students performed parametric sweeps and optimizations in CST; the software (machine) provided instant feedback on S-parameters, Smith charts, and 3D radiation patterns; the students (humans) needed to interpret the data, understand the physical meaning of impedance transformation, and accordingly adjust the matching circuit topology and parameters. The teacher's role shifted to that of a guide, driving deep thinking through strategic questions (e.g., "Why choose a single-stub match over a quarter-wave match?" "Looking at the Smith chart, is your matching path optimal?").

Phase 2: Value Reflection and Ethical Deliberation. IPE elements were naturally internalized during the iterative optimization process. In the repeated iterative design process, students often underwent dozens or even dozens of "design-simulation-analysis" cycles to improve bandwidth by 2MHz or gain by 0.5dBi, thereby profoundly honing the craftsmanship spirit of excellence and rigorous truth-seeking. Simultaneously, the teacher guided the AI learning companion to push prompts such as "While pursuing high performance, did your design consider power consumption and cost?" or "If this antenna were used in medical equipment, what higher standards should its radiation safety meet?" These prompts prompted students to synchronously examine the potential social and environmental impacts of their engineering decisions while focusing on technical optimization, thereby internalizing awareness of engineering ethics.

Phase 3: Comprehensive Evaluation and Outcome Transfer. At the project conclusion, each group submitted a comprehensive report including design rationale, simulation data, and ethical considerations, followed by a defense.

Phase 4: Reflection and Sublimation. The experience from this microstrip antenna design was transferred to a broader perspective of microwave systems engineering. For example, comparing the different design philosophies of satellite-borne large antennas and mobile phone built-in antennas, and reviewing breakthroughs in areas like phased array radar and millimeter-wave communication in China, enabled students to deeply understand the "big principles" and "great sentiments" embodied behind the "small antenna," ultimately achieving the final leap from skill mastery to value identification and elevated perspective.

2.2.3. Teaching effectiveness evaluation and analysis

To comprehensively evaluate the effectiveness of the teaching model, a diversified assessment method was adopted, revealing significant improvements in students across multiple dimensions including academic goals, core competencies, and values. At the academic level, compared to previous classes using traditional design experiments, students in this cohort showed marked progress in "antenna performance optimization completion rate" (e.g., the rate of achieving S11 < -15dB increased from 65% to 92%) and the "theoretical depth of design reports." For instance, over 80% of the reports could accurately use Smith charts to analyze the matching process, rather than simply listing data. In terms of core competencies, student feedback through questionnaires and interviews indicated an enhanced ability to deeply integrate abstract theory into engineering practice and actively balance performance, cost, and manufacturing complexity in their design schemes, demonstrating comprehensive engineering thinking. More importantly, the effectiveness of IPE was simultaneously evident: students' sentiment of serving the country through science and technology was internalized from an external call into a genuine driver, with some students remarking that their design felt like contributing a tiny "cell" to the "smart city" blueprint. Furthermore, all groups voluntarily added a "Design Trade-offs and Social Impact" section in their reports, consciously discussing issues like power consumption, environmental protection, and cost, marking the preliminary establishment of ethical awareness for responsible innovation.

2.2.4. Teaching reflection and iteration

While achieving significant results, this teaching practice also revealed several key issues requiring optimization, pointing the direction for the model's continuous iteration:

Some students exhibited a "black box" reliance on simulation software, being satisfied with aesthetically pleasing result curves but neglecting to investigate the impact of underlying algorithm principles and mesh settings on accuracy. To address this, the next teaching cycle will mandate the inclusion of a "Simulation Setup Reliability Analysis" in reports and introduce cross-verification using analytical formulas or equivalent circuit models to strengthen critical thinking.

Uneven participation still existed within some groups during collaborative inquiry, affecting the overall learning depth. Subsequently, leveraging the contribution logs from online collaboration platforms, combined with mechanisms for "intra-group peer evaluation" and "individual defense," will be used to ensure deep participation from every student.

The interactivity of the current AI learning companion remains limited. Its preset text prompts sometimes fall short in responding to diverse, immediate student thinking. Future plans involve building a richer case library based on accumulated student operation and dialogue data and introducing large language model technology to enhance its natural language interaction and contextualized guidance capabilities.

3. Conclusion

From the perspective of "human-machine shared intelligence," this paper explored and constructed a new pathway for integrating IPE into ROT: the "Human-Machine Collaboration, IPE Integration, Inquiry-Driven" model. The core concept of this pathway lies in: cracking teaching difficulties through technological empowerment, and creating opportunities for IPE through model reconstruction. Practice has proven that this new pathway, using electromagnetic fields and waves related courses as the vehicle, can effectively address the problems of the "awkward integration" of IPE and the "difficulty in conducting" ROT. On one hand, it utilizes human-machine collaboration to make abstract field and wave concepts perceivable and interactive, greatly enhancing the depth and breadth of ROT. On the other hand, it integrates IPE into the entire inquiry process, allowing students to internalize scientific spirit, engineering ethics, and national sentiments through firsthand experience in solving real problems, achieving a "silent moistening" educational effect.

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