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Research on the Cultivation and Teaching Practice of Design Thinking of Absorbing Materials Based on Electromagnetic Parameters

Rui Guo[1,2,3]

[1]College of Materials Science and Engineering, Hebei University of Science and Technology, Shijiazhuang 050018, Hebei, China
[2]Hebei Key Laboratory of Flexible Functional Materials, School of Materials Science and Engineering, Hebei University of Science and Technology, Shijiazhuang 050000, Hebei, China
[3]Hebei Short Process Steelmaking Technology Innovation Center, Hebei University of Science and Technology, Shijiazhuang 050000, Hebei, China

**Author to whom correspondence should be addressed.*

Abstract: As critical materials in defense, military, and electronic information fields, microwave-absorbing materials require precise control and optimal matching of electromagnetic parameters. Current teaching in materials science programs at universities faces challenges such as disconnection from engineering practice and insufficient development of students 'design thinking and innovation capabilities. This study focuses on electromagnetic parameters to establish a "knowledge-ability-cultivation" tripartite teaching objective, optimize the curriculum system, innovate diversified teaching methods, develop a scientific evaluation framework, explore pathways for cultivating design thinking, and validate the model's feasibility, thereby providing references for curriculum reform in materials science programs.

Keywords: Electromagnetic parameters; Microwave absorbing materials; Design thinking; Teaching practice

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1. Introduction

The escalating challenges of electromagnetic interference and radiation have spurred a surge in demand for absorptive materials in fields like electromagnetic compatibility and stealth technology. The core performance of these materials hinges on precise control of electromagnetic parameters, making design thinking based on electromagnetic parameters a critical skill for professionals. However, current university curricula overemphasize abstract theoretical explanations and basic experimental operations, while neglecting targeted cultivation of design and systems thinking. This gap hinders students from translating theoretical knowledge into practical design capabilities, creating a disconnect with industry demands. Drawing on successful teaching reforms in materials science, this paper explores the pedagogical positioning, content framework, and practical approaches for absorptive material design thinking, providing actionable insights for curriculum innovation.

2. Core connotation and teaching orientation of design thinking for absorbing materials based on electromagnetic parameters

The design philosophy of electromagnetic parameter-based absorptive materials centers on electromagnetic parameter regulation, integrating theoretical analysis, numerical simulation, experimental verification, and innovative optimization into a systematic approach. Its essence is profoundly embodied in the complete logical chain of "goal orientation-parameter correlation-system optimization-practical verification". At the goal orientation level, precise focus must be placed on specific performance requirements of absorptive materials, clarifying key design indicators such as target frequency bands, reflection loss thresholds, and effective bandwidth to ensure targeted design and avoid blind experimentation. In terms of parameter correlation, a deep understanding is required of the intrinsic relationships between two core electromagnetic parameters (dielectric constant and magnetic permeability) with impedance matching principles and energy loss mechanisms (including conductive loss, polarization loss, and hysteresis loss). This involves clearly comprehending how parameter value ranges and frequency dependence nonlinearly affect absorptive performance, which forms the theoretical foundation for material optimization. For system optimization, comprehensive approaches including material composition regulation, microstructure design, and composite modification techniques should be employed to achieve precise parameter matching and synergistic optimization. This ensures both absorptive performance compliance and material mechanical stability, environmental adaptability, and cost controllability to meet comprehensive engineering application requirements. At the practical verification stage, professional numerical simulation tools like HFSS and COMSOL, combined with precision testing equipment such as vector network analyzers, are utilized to conduct simulation and experimental validation of design proposals.

Through a closed-loop iterative process of "design-verification-improvement", parameter combinations and structural designs are continuously optimized to ensure final products meet expected performance standards. The cultivation of design thinking fundamentally aims to guide students beyond the passive learning model of "theoretical memorization and experimental operation," establishing an active thinking paradigm of "requirement decomposition, theoretical support, solution design, and practical verification." This approach achieves the core goal of transforming knowledge accumulation into capability development. In terms of teaching orientation, the design thinking cultivation for electromagnetic parameter-based absorptive materials must closely align with the talent development objectives of materials science disciplines, deeply integrate industry demands and cutting-edge academic trends, and comprehensively incorporate design thinking throughout both theoretical and practical teaching processes. The core philosophy of "thinking leadership, competency-based education, and quality-oriented development" advocated in the teaching reform of basic materials science courses in the new era equally applies to absorptive materials design courses. It requires breaking through traditional teaching dilemmas of "separation between theory and practice, disconnection between knowledge and application," and constructing an integrated teaching system of "theoretical explanation, simulation modeling, experimental operation, and comprehensive design." By strengthening the deep integration of electromagnetic parameter theory with engineering design practice, students are guided to transform abstract parameter knowledge into concrete design tools, focusing on cultivating their ability to extract core issues from complex engineering requirements and apply parameter control methods to solve practical problems.

Meanwhile, through rich case analysis and real project practice, we cultivate students' scientific literacy, innovative awareness, and rigorous engineering thinking, helping them establish a "performance-parameter-structure" linkage cognition. This lays a solid foundation of capabilities and cognitive support for their future work in areas such as microwave absorbing material R&D and electromagnetic compatibility design.

3. Construction of the teaching system for cultivating design thinking of absorbing materials based on electromagnetic parameters

3.1. Construction of teaching objectives

To cultivate design thinking in electromagnetic parameter-based absorptive materials, an integrated "knowledge-competency-skill" teaching framework should be established to ensure targeted and systematic instruction. The knowledge objectives require students to master fundamental concepts, measurement methods, and frequency characteristics of electromagnetic parameters (dielectric constant, permeability), understand absorption mechanisms including resistive loss, dielectric loss, and hysteresis loss, and comprehend the correlation between electromagnetic parameters and reflection loss/absorption bandwidth. Core design techniques such as component regulation, structural design, and composite modification must be acquired. The blended teaching approach for applied talent development emphasizes balancing theoretical depth with practical application, ensuring students solidify theoretical foundations while bridging theory-to-practice. Competency objectives focus on electromagnetic parameter regulation, material design, innovative practice, and teamwork. Through instruction, students should develop parameter adjustment strategies based on performance requirements, utilize simulation software for structural design and performance prediction, and optimize solutions through experimental testing. Innovative experimental teaching practices demonstrate that absorptive materials education should adopt project-driven tasks, strengthen practical components, and facilitate the transformation of theoretical knowledge into design capabilities. The literacy objectives emphasize cultivating engineering thinking, scientific literacy, a sense of responsibility, and sustainable development concepts. They guide students to holistically evaluate wave-absorbing performance, cost-effectiveness, and environmental friendliness, fostering a systems engineering mindset. By sharing cutting-edge developments, the program ignites a scientific inquiry spirit while highlighting the critical role of wave-absorbing materials in national defense and electromagnetic compatibility. This approach strengthens professional accountability. The curriculum reform explicitly requires balancing knowledge transmission with competency development, ensuring students' holistic growth.

3.2. Optimize teaching content

The optimization of teaching content should center on electromagnetic parameters, establishing a tripartite system of "theoretical module-practical module-case module" to achieve deep integration of theory and practice. The theoretical module covers the fundamentals of electromagnetic parameters, classification and mechanisms of absorptive materials, correlation laws between parameters and performance, and design principles. In teaching, we should draw on the experience of teaching reforms in microelectronic material design and device simulation, incorporating the basics of electromagnetic parameter simulation [1]. This enables students to master the analysis of parameter impacts on absorptive performance through simulation tools. Meanwhile, referencing the teaching reform approach of the Fundamentals of Materials Science course, we should simplify abstract derivations, strengthen the connection between theory and engineering practice, and illustrate the practical significance of electromagnetic parameter regulation through concrete cases. The practical module serves as the core vehicle for cultivating design thinking, including electromagnetic parameter testing experiments, absorptive performance testing experiments, design simulation practices, and comprehensive design projects. Electromagnetic parameter testing experiments focus on operating vector network analyzers and other equipment to develop parameter testing and error analysis skills; absorptive performance testing experiments emphasize mastering reflection loss measurement methods; design simulation practices train structural design and performance prediction capabilities through software like HFSS and COMSOL; comprehensive design projects require students to complete the full process of "requirement analysis-parameter design-simulation optimization-experimental verification" in groups. Innovative experimental teaching experiences, such as enhancing practical skills through composite material synthesis practices, demonstrate that the practical module should emphasize hierarchical progression, gradually improving students' design thinking and practical abilities from basic experiments to comprehensive projects [2]. The case module presents design examples of both traditional microwave-absorbing materials (e.g., ferrite and carbonyl iron powder-based materials) and novel materials (e.g., nanocomposites and two-dimensional materials). It analyzes parameter tuning strategies and structural design approaches for different materials. This interactive teaching method, effectively applied in engineering classrooms, enhances practical teaching through case analysis. It helps students intuitively understand the application process of design thinking while introducing cutting-edge industry cases and research achievements, thereby broadening professional perspectives and inspiring innovative ideas.

3.3. Innovation of teaching methods

Innovations in teaching methodologies should integrate blended, project-based, and interactive approaches to establish diversified instructional models. Blended learning draws on practical experience from foundational materials science courses, combining the strengths of online and offline teaching [3]. Online platforms provide resources such as MOOCs and virtual simulation tools for electromagnetic parameter theory and simulation software operations, supporting pre-class preparation and post-class review. Offline classes focus on explaining key concepts, conducting case analyses, facilitating group discussions, and offering practical guidance, forming a closed loop of "online self-directed learning + offline in-depth interaction" to meet personalized learning needs and enhance teacher-student and peer interactions. Project-based teaching drives learning through real-world design projects, integrating curriculum content throughout the implementation process. Examples include projects like "Design of Absorbent Materials for Specific Frequency Bands" and "Development of High-Performance Lightweight Absorbent Materials." Students work in groups to complete tasks such as requirement analysis, solution design, parameter optimization, simulation refinement, and experimental verification, submitting design reports and outcomes. Teachers act as facilitators, assisting in solving technical challenges and guiding students to apply design thinking. Experience shows that project-driven experimental teaching enhances students' innovation capabilities, stimulates learning initiative, strengthens the integration of theory and practice, and promotes the development of design thinking. Interactive teaching methods leverage hands-on engineering classroom experiences, enhancing participation through discussions, case debates, and design project presentations. In theoretical instruction, open-ended questions are designed to explore parameter control strategies and wave-absorbing mechanisms. Practical sessions feature collaborative project showcases and peer evaluations, fostering knowledge exchange and creative thinking. By incorporating industry expert lectures and corporate field studies, students gain insights into real-world engineering challenges, expand their design perspectives, and break free from traditional passive learning. This approach ignites learning motivation while developing critical thinking and communication skills.

4. Teaching practice and the effect of cultivating design thinking of absorbing materials based on electromagnetic parameters

4.1. Implementation path of teaching practice

The teaching practice follows a closed-loop approach of "pre-class preparation-classroom instruction-post-class practice-outcome evaluation" to ensure the coherence and effectiveness of design thinking cultivation. During the pre-class preparation phase, online platforms are utilized to distribute resources such as theoretical videos on electromagnetic parameters, simulation software tutorials, and case studies. Students are required to complete knowledge acquisition, online assessments, and preparatory reports, mastering core theories and tool usage methods. Thought-provoking questions like "The Impact of Electromagnetic Parameters on Absorption Performance" and "Key Steps in Absorbing Material Design" are designed to stimulate active thinking and lay the groundwork for classroom instruction. The classroom teaching adopts a process of "theoretical explanation, case analysis, group discussion, and practical guidance." Teachers focus on explaining core concepts such as parameter-performance correlations and design principles based on feedback from preparatory work. By analyzing typical cases, they demonstrate the application of design thinking and distill design methodologies. Discussion tasks like "Parameter Optimization Scheme for Absorbing Materials in Specific Frequency Bands" are set to foster intellectual exchange. On-site guidance is provided for simulation design and experimental operations to address technical challenges. Interactive teaching in engineering classrooms emphasizes targeted engagement, so discussions and guidance are all centered around the core objectives of design thinking cultivation to ensure teaching effectiveness. The post-class practice centers on comprehensive design projects, where students work in groups to complete the full design process. Through literature review, conceptual design, simulation optimization, and experimental testing, they progressively enhance their design thinking and practical skills. Teachers monitor project progress via online platforms, organize regular offline Q&A sessions and interim reports, and promptly address design challenges. The innovative experimental approach, featuring continuous guidance and phased feedback, has proven effective for comprehensive design projects, ensuring students refine their proposals and strengthen design thinking through hands-on practice. Additionally, students are encouraged to participate in academic competitions and research projects, achieving an organic integration of teaching practice and extracurricular expansion.

4.2. Evaluation system of teaching effect

We have established a diversified evaluation system integrating "formative assessment + summative assessment + comprehensive competency evaluation" to holistically assess students' knowledge mastery, design thinking proficiency, and practical skills. The formative assessment accounts for 50% of the total score, covering four components: pre-class preparation (10%), classroom participation (15%), project progress (15%), and lab reports (10%). Preparation quality is evaluated through online quizzes and submitted reports, while classroom performance is assessed based on engagement levels, speech clarity, and design concept articulation. Project progress is evaluated through periodic progress reports and analysis of plan completeness and logical coherence. Lab reports focus on data accuracy, analytical depth, and methodological rigor. The teaching reform emphasizes that formative assessment comprehensively reflects learning processes and skill development, thus running throughout the entire teaching cycle to provide timely feedback and support targeted instructional adjustments [4]. The summative assessment accounts for 30% of the total score, centered on comprehensive design project outcomes, including design reports (15%), experimental results (10%), and defense performance (5%). Design reports are evaluated for innovative concepts, feasible solutions, and rational parameter adjustments. Experimental results are assessed based on the quality of absorbed wave performance test data. Defense performance evaluates understanding of design concepts, problem-solving capabilities, and communication skills, ensuring a balanced assessment of design thinking and practical abilities while maintaining objective and fair outcomes. The comprehensive competency assessment accounts for 20% of the evaluation, covering three key components: teamwork (8%), innovative thinking (6%), and accountability (6%). It combines peer group evaluations with teacher assessments to evaluate collaborative performance. Innovative thinking is assessed through the originality of design proposals and unique problem-solving approaches, while accountability is measured by the rigor of experimental procedures and report writing. This evaluation system embodies the "competency-first" teaching philosophy, fostering students' holistic development.

4.3. Practice reflection and improvement strategy

Three prominent issues have been identified in teaching practice: First, significant disparities in students' theoretical foundation of electromagnetic parameters, with some struggling to quickly grasp design principles and methods; Second, insufficient practical resources such as simulation software operation and experimental equipment, which constrain practical teaching effectiveness; Third, weak innovation awareness among some students, resulting in design proposals lacking relevance and originality.

To address foundational differences, a tiered teaching model was adopted. Based on pre-test scores and learning abilities, students were divided into three groups: the Basic Group, the Enhancement Group, and the Innovation Group. The Basic Group focused on reinforcing electromagnetic parameter fundamentals and basic design methods through specialized exercises and foundational experiments. The Enhancement Group received increased simulation design and optimization training, along with advanced project practices. The Innovation Group was encouraged to participate in cutting-edge design projects and research topics to cultivate innovation capabilities, while online platforms provided personalized learning resources to meet diverse needs.

To address resource shortages, multiple channels were utilized to integrate resources. On-campus efforts optimized experimental resource allocation by extending equipment availability and improving utilization efficiency through reservation systems and group rotation training. Off-campus collaborations strengthened school-enterprise partnerships by introducing corporate simulation platforms and experimental equipment, establishing off-campus practice bases, and organizing students to participate in real-world project designs.

These initiatives enhanced engineering practice capabilities. The experience of improving practical outcomes through resource integration in experimental teaching can serve as a reference for hardware support. To address the issue of insufficient innovation awareness, we will strengthen cultivation through multidimensional approaches, enrich case-based teaching content by incorporating more industry innovation cases and cutting-edge research achievements, and analyze innovative design concepts. We will optimize project design tasks by setting open-ended topics to encourage students to break traditional patterns and explore novel parameter control strategies and structural design solutions. An innovation incentive mechanism will be established to recognize and reward innovative design achievements, with innovation performance incorporated into the evaluation system. Industry experts will be invited to deliver frontier lectures, sharing innovative experiences to inspire creativity. Regular design exchange meetings and innovation thinking workshops will be organized to foster a vibrant innovation atmosphere [5].

5. Epilogue

Cultivating design thinking for electromagnetic parameter-based absorptive materials is a vital component in materials science education, significantly enhancing students' engineering design capabilities and innovative awareness. The proposed "trinity" teaching objectives, "three-module" content framework, diversified teaching methodologies, and comprehensive evaluation system establish a robust practical model that effectively bridges the gap between traditional teaching theories and real-world applications. Future initiatives will deepen pedagogical reforms, strengthen industry-academia collaboration, incorporate cutting-edge technologies and engineering case studies, continuously refine teaching content and methods, and improve the relevance and effectiveness of talent development, ultimately producing more high-caliber absorptive materials designers for the industry.

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