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Research on the Teaching Design of Nondestructive Testing Course Based on Engineering Ability Training

Wei Lihong[1]

[1] School of Intelligent Manufacturing, Leshan Vocational and Technical College, China
Correspondence: Wei Lihong, School of Intelligent Manufacturing, Leshan Vocational and Technical College, Leshan, China.

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Abstract

As an essential foundational course for majors related to materials, machinery, and testing, the course "Nondestructive Testing" is both theoretical and practical, with an engineering-based approach. Based on the current teaching practices of colleges and universities, this paper conducts a systematic exploration of course content design, teaching method reform, the introduction of engineering cases, and practical teaching links. Through the implementation of diversified teaching modes such as project-driven teaching, case teaching, and hybrid teaching, students' understanding and application ability of nondestructive testing technology have been significantly improved. In light of the challenges posed by limited resources and uneven student foundations in the teaching process, corresponding improvement measures are proposed. The research results provide a valuable reference for enhancing the teaching quality and the impact of talent development in the course <Nondestructive Testing>.

Keywords: Non-Destructive testing, curriculum reform, project-based learning

1. Introduction

With the ongoing advancement of high-quality development in China's manufacturing industry, the demand for interdisciplinary and application-oriented technical talents in engineering fields is becoming increasingly urgent. As a critical method for ensuring material quality and the safe operation of equipment, non-destructive testing (NDT) is widely used in key industrial sectors, including aerospace, petrochemicals, rail transit, and nuclear engineering. It not only safeguards industrial production but also reflects the core competencies required in modern engineering practice.

As an essential supporting course in engineering majors such as materials, mechanical, and energy engineering, NDT has become an indispensable part of the engineering education system. However, many universities still face challenges in NDT teaching, including an overemphasis on theory over practice, a focus on knowledge transmission over skills development, a weak alignment with industry applications, insufficient practical training, and inadequate development of students' innovative capabilities. These challenges hinder the goal of training high-quality technical professionals under the framework of the "New Engineering" initiative. The New Engineering initiative emphasizes interdisciplinary integration, industry–education collaboration, practice orientation, and continuous innovation, placing higher demands on curriculum structure and pedagogical approaches. In this context, exploring student-centered, industry-driven, and technology-enhanced teaching models for NDT courses has become a vital task for curriculum reform and instructional innovation.

This study proposes an NDT teaching design based on engineering competency development, aiming to enhance teaching effectiveness. By integrating case-based learning, project-driven instruction, and blended learning strategies, a comprehensive system is constructed that bridges theory and practice. This approach supports the improvement of students' overall competence and job readiness. Drawing on practical teaching experience, this paper presents and validates a design framework intended to inform NDT curriculum reform and contribute to the cultivation of innovative, high-quality technical talent in response to industry needs.

2. Course Content and Instructional Design

The Nondestructive Testing course covers commonly used testing techniques, including ultrasonic testing, radiographic testing, magnetic particle testing, penetrant testing, and eddy current testing. Characterized by strong theoretical foundations and broad engineering applications, the course serves as a core subject for engineering majors, including materials, mechanical, and energy engineering. To support the integrated development of students' theoretical understanding and practical abilities, the course content and instructional design should emphasize the following three aspects:

(1) Integration of Fundamentals and Engineering Applications

The course should systematically introduce essential physical principles such as wave propagation, electromagnetic induction, and capillary phenomena to establish a solid theoretical foundation. Simultaneously, it should incorporate real-world engineering scenarios—such as weld inspection, pressure vessel evaluation, and casting defect identification—to conduct case-based teaching. This approach guides students in understanding the core logic of "testing purpose—testing content—method selection," thereby enhancing their ability to analyze and solve practical engineering problems. The dual emphasis on theory and application enables students to develop both a deep understanding of core concepts and a strong awareness of real-world engineering contexts.

(2) Modular Teaching Structure and Interdisciplinary Resource Integration

Based on the technical characteristics of different testing methods, the course can be designed using a modular approach along six key dimensions: "principle–equipment–method–signal interpretation–defect evaluation–engineering case." Experimental sessions and case-based exercises should accompany each module to promote hands-on learning and internalization of knowledge. The modular structure also facilitates cross-disciplinary collaboration and resource sharing, supporting the integration of content across engineering programs. Additionally, it enables greater flexibility and customization of instruction based on students' backgrounds, thereby enhancing the course's adaptability and teaching effectiveness.

(3) Integration of Industry Standards and Professional Norms

As nondestructive testing practices are highly reliant on standardized procedures, the course should incorporate relevant national and international standards, such as GB/T 12604 and ISO 9712. This will enhance students' awareness of quality control and professional compliance. Teaching activities such as standards interpretation, technical documentation writing, and analysis of inspection reports can be employed to cultivate rigorous engineering thinking and professional communication skills. To further develop practical competencies, students may also be guided to engage in comprehensive tasks, such as simulation-based analysis, technique selection, and quality assessment, based on real-world engineering problems. This approach broadens their practical experience and industry awareness.

3. Teaching Method Reform and Implementation

In response to the demands of the "New Engineering" education initiative and the growing need for interdisciplinary and application-oriented engineering talent, the Nondestructive Testing course was redesigned with a focus on enhancing student engagement, strengthening practical engineering skills, and fostering autonomous learning abilities. The reform explores and implements an integrated approach through three key pedagogical strategies.

3.1 Case-Based Teaching

First, the case-driven teaching method uses typical engineering cases as a carrier to construct a systematic teaching process of "problem guidance-knowledge construction-application expansion". In the teaching process, by carefully selecting typical and representative engineering cases such as weld ultrasonic testing, aircraft skin crack assessment, and petrochemical pipeline corrosion monitoring, the theoretical knowledge of non-destructive testing is closely combined with practical engineering problems to help students deeply understand the physical principles, process requirements and practical application value behind the detection technology in industry. Such cases not only encompass the core technologies of various detection methods but also involve complex working conditions and typical defect types, allowing students to experience the impact of diverse engineering scenarios on the design of detection schemes.

In teaching, teachers make full use of multimedia resources, such as high-definition detection process videos, professional simulation demonstration software (such as CIVA, VGStudio) and three-dimensional structural models, to visualize the more abstract physical phenomena such as sound wave propagation and electromagnetic induction in traditional classrooms, intuitively display the generation and transmission process of defect signals, and significantly enhance the visual impact and interactivity of the classroom. Through dynamic simulation and virtual experiments, students can independently observe and adjust parameters, perceive the real-time impact of different variables on the detection effect, and stimulate their interest in learning and motivation for active exploration.

In addition, the course has regular case analysis and reporting sessions, encouraging students to conduct in-depth research and technical analysis of designated or self-selected industrial cases in groups. In the preparation stage, students must consult relevant technical information, testing standards, and the latest scientific research results and comprehensively apply the theoretical knowledge they have learned to complete defect identification, method selection, and optimization scheme design. In the classroom report, students present their research results in various forms, such as oral presentations, PowerPoint presentations, and technical demonstrations, and engage in questions and discussions with teachers and peers. This "listen-see-think-speak" teaching model not only promotes students' systematic integration and deepening of knowledge but also greatly exercises their logical thinking ability, teamwork ability and engineering communication ability.

Through case-driven teaching, students can train their ability to analyze and solve problems in a simulated real engineering environment, cultivate the awareness of formulating reasonable detection strategies based on actual needs, and improve the level of organic integration of theory and practice, laying a solid foundation for their subsequent non-destructive testing and related engineering technology work[10].

3.2 Project-Based Learning (PBL)

Secondly, Project-Based Learning (PBL) has played a significant role in enhancing students' comprehensive practical skills and team collaboration abilities. Based on real engineering demands, the course has been designed around a series of group projects, requiring students to work in teams of 3 to 5 members to complete comprehensive engineering tasks, such as designing a non-destructive testing (NDT) scheme for a specific structural component. The project tasks encompass the full engineering process, including defect risk analysis, selection of testing methods, process planning, standards matching, and final technical report writing, thereby thoroughly developing students' engineering thinking and problem-solving capabilities.

During project implementation, instructors serve not only as knowledge providers but also as process facilitators and resource coordinators. The teaching team establishes clear stage goals, organizes regular progress checks and interim presentations, and provides timely feedback to help students identify and resolve issues encountered in scheme design, experimental operation, and data analysis. Students are actively guided to consult domestic and international standards, academic literature, and industry regulations, fostering their ability to access and apply technical knowledge independently and effectively.

Moreover, the projects emphasize the internal division of labor and collaboration within teams, promoting growth in role assignment, time management, and communication skills. Throughout the project process, students are expected to continually synthesize the technical knowledge they have acquired, prepare detailed technical reports, and deliver final presentations. Through multiple rounds of reporting and peer review, students not only strengthen their skills in logical communication and technical writing but also improve their ability to respond to professional questions, thereby enhancing their professional competence.

This project-based learning approach closely integrates theoretical instruction with hands-on tasks, helping students build a systematic understanding of engineering knowledge, foster interdisciplinary integration thinking, and develop both technical and managerial capabilities. Simulating real-world engineering scenarios enables students to prepare in advance for the comprehensive skill requirements of future positions, thus laying a solid foundation for their transition into professional engineering roles.

3.3 Blended Learning

The course employs a blended teaching model that integrates both online and offline components, effectively combining the advantages of digital instructional resources with traditional classroom instruction to construct a multidimensional, process-oriented learning system. This approach aims to enhance instructional flexibility, increase student engagement, and improve learning outcomes.

Online Component: Leveraging a Learning Management System (LMS), a structured and expandable course resource library has been developed. It includes national and industry-standard documents, instructional videos on nondestructive testing equipment, MOOC micro-courses, and virtual simulation experiments based on virtual reality (VR) technology. These resources are accessible to students for pre-class preparation, targeted remediation, and post-class review. The platform also features online quizzes, interactive Q&A sessions, and downloadable materials, enabling instructors to monitor student progress in real time and implement precision teaching strategies with precision. The online component transcends the limitations of time and space, enhancing learning autonomy and supporting personalized learning experiences.

Offline Classroom: In-person sessions focus on the in-depth explanation of key concepts and core technical skills. A variety of instructional strategies are employed, including physical model demonstrations, equipment operation training, group discussions, case studies, and hands-on experiments. Instructors emphasise the integration of theoretical principles with engineering applications by designing problem-based teaching scenarios that align with real-world industry practices. Students engage in observation of real samples and participate in hands-on practice to gain an intuitive understanding of NDT technologies, thereby improving their technical proficiency and engineering analysis capabilities.

Flipped Classroom Elements represent a significant innovation in this course's pedagogical design. In selected instructional units, students, organised into groups, assume the role of "classroom instructors." They are responsible for conducting literature reviews, synthesizing information, structuring content, and designing instructional materials. During class, these student-led teams deliver presentations, explain technical concepts, and defend their proposed solutions. The instructor acts as a facilitator and evaluator, providing feedback and organizing peer assessments. This approach significantly enhances student engagement and depth of learning while cultivating skills in information retrieval, logical articulation, language organization, and public speaking. The flipped classroom promotes a shift from passive reception to active construction of knowledge, fully engaging students in the learning process.

In summary, the blended teaching model combines the strengths of both online and offline instruction to form a diverse, flexible, and efficient educational framework. It accommodates the varied learning needs of students and provides a practical pathway for deep integration of engineering education and information technology. Through this model, students achieve comprehensive development across knowledge acquisition, skill enhancement, and professional competency formation within an interactive and learner-centred environment.

4. Teaching Effectiveness Evaluation and Feedback

The Nondestructive Testing course targets students in the "3+2" vocational–undergraduate integrated education program. These students typically exhibit relatively weak theoretical foundations, strong hands-on abilities, and a clear employment orientation. Accordingly, the course reform was designed around the principle of "understandable, applicable, and practical," shifting the instructional focus from passive knowledge transmission to competency enhancement and professional literacy development. The effectiveness of the reform was evaluated through student questionnaires, structured interviews, theoretical assessments, and practical project evaluations. Key findings are summarized below.

4.1 Increased Student Satisfaction

At the end of the semester, a survey was distributed to all enrolled students, yielding 136 valid responses. Results indicate a significant improvement in students' satisfaction with the course. 93% of students agreed that the course content is closely aligned with future job requirements, thereby enhancing their motivation and the relevance of the learning. 89% reported that the use of case studies and project-driven learning significantly reduced the difficulty of understanding abstract concepts. 86% believed that the modular structure of the course facilitated better knowledge integration, particularly in method comparison and selection.

Additionally, qualitative feedback indicated that students appreciated the stronger connection between theory and practice, as well as the emphasis on teamwork and communication. Overall satisfaction ratings were markedly higher than those for previous offerings of the course.

4.2 Improved Theoretical Understanding and Engineering Cognition

The instructional strategy emphasized a dual approach: "visualized principles + real-world case integration." Teaching methods included animated simulations, live demonstrations using inspection equipment, schematic illustrations, and group discussions. This approach supported students in constructing a structured and applied knowledge framework. Post-course theoretical tests revealed notable improvements in students' understanding of key concepts, including testing principles, signal interpretation, and defect classification. The average score increased by approximately 12%, while the failure rate decreased from 22.5% to 9.4%. Students particularly valued the visualization tools, which they felt "made invisible physical processes tangible" and significantly aided comprehension.

These outcomes demonstrate that integrating conceptual visualization with contextual engineering scenarios enhances both academic understanding and practical relevance.

4.3 Enhanced Practical Skills and Project Competence

Project-based learning was implemented throughout the course to cultivate comprehensive NDT skills aligned with industry standards. Students were tasked with completing authentic engineering assignments, including:

designing inspection procedures, selecting applicable standards (e.g., GB/T 12604, ISO 9712), setting instrument parameters, writing technical reports.

Performance evaluation revealed the following:

Over 80% of students completed the full set of inspection tasks independently. In the final practical exam, students demonstrated high levels of accuracy in signal identification, procedural compliance, and report clarity. Several students subsequently participated in technical competitions and industry internships, receiving positive feedback from external evaluators.

The project-driven structure effectively fostered critical thinking, problem-solving, collaboration, and communication—key competencies for professional readiness in engineering settings.

5. Challenges in Teaching and Recommendations for Improvement

Despite the positive outcomes achieved in course content reform, instructional methods, and assessment systems, several challenges remain in the practical implementation of teaching. These challenges hinder the sustainability and scalability of teaching quality improvements and require targeted interventions. The key issues and corresponding recommendations are as follows:

5.1 Limited Equipment Resources and Restricted Practice Opportunities

The current availability of nondestructive testing (NDT) equipment is insufficient in both quantity and technical capability to meet the demands of diversified teaching tasks. Some of the existing instruments are outdated and support only a narrow range of testing methods, limiting students' exposure to ultrasonic, radiographic, magnetic particle, and eddy current testing. Furthermore, the limited number of workstations constrains hands-on training, especially in large-class settings, resulting in fragmented and insufficient practice.

Recommendation:

It is essential to modernize laboratory infrastructure by updating and expanding equipment. Simultaneously, a dual-track practice model should be established through collaboration with industry and professional testing institutions—combining on-campus virtual simulation platforms with off-campus enterprise practice bases. This blended model can improve both instructional efficiency and student engagement in real-world engineering environments.

5.2 Fragmented Understanding of Standards and Insufficient Engineering Thinking

Although students generally grasp the theoretical principles and basic procedures of NDT, their knowledge of industry standards, process documentation, and defect evaluation criteria is often fragmented and shallow. This lack of systemic understanding hinders the development of engineering thinking grounded in compliance and precision.

Recommendation:

The course should place greater emphasis on the structured integration of standards. Modular teaching components such as "Standard Interpretation", "Procedure Analysis", and "Technical Report Writing" should be incorporated into the curriculum. Students should be encouraged to actively consult and apply relevant standards (e.g., GB/T, ISO 9712) during project tasks. This will foster a stronger sense of quality awareness, regulatory compliance, and professional communication.

5.3 Lack of Cross-disciplinary Integration and Limited Knowledge Application

Currently, the course content remains largely confined to core NDT knowledge and lacks integration with related disciplines such as mechanical design, artificial intelligence (AI)-based defect recognition, and intelligent manufacturing. This siloed approach limits students' ability to apply their knowledge creatively and engage in interdisciplinary problem-solving.

Recommendation:

Aligned with the "New Engineering" initiative, the course should be embedded within a cluster of interdisciplinary modules that promote knowledge transfer and holistic skill development. Project-based assignments should encourage students from different majors to collaborate in mixed teams. Faculty can further support this by offering modular project courses or interdisciplinary engineering workshops, thereby facilitating resource sharing, curriculum synergy, and joint talent development across disciplines.

6. Conclusion

As a core technical course in engineering programs, Nondestructive Testing plays a vital role not only in enhancing course-level quality but also in shaping the professional competencies of high-level technical talent. Against the backdrop of advancing "New Engineering" education and deepening industry–education integration, the course is expected to evolve from a traditional "technical training" model toward one centred on competency building and professional literacy development.

Looking forward, further reforms should continue to promote the integration of theory and practice, technology and standards, as well as classroom and project-based learning. Anchored in real engineering scenarios and empowered by modern information technologies, the course should strive to construct an instructional framework that is industry-aligned, application-oriented, and future-focused. Through ongoing innovation in curriculum design, pedagogical strategy, and cross-disciplinary collaboration, the course can comprehensively enhance students' technical capabilities, creative thinking, and job readiness—ultimately contributing to the cultivation of innovative professionals equipped for the high-quality development of the manufacturing industry.

References

[1] Ji, H., Liu, B., & Qi, H. (2022). Reflections and exploration on integrating ideological and political education into the teaching of “Nondestructive Testing Technology”. *Creative Education Studies, 10*, 2515. https://doi.org/10.12677/CES.2022.1010396

[2] Grosse, C. U., & Pinkert, K. (2016). New concepts for the academic education in the field of NDT at a German technical university. In *Proceedings of the 19th World Conference on Nondestructive Testing (NDT)*, DGZfP, München, We-3-C-1.

[3] Arndt, R. W., Grosse, C. U., Niederleithinger, E., Mähner, D., Taffe, A., & Algernon, D. (2025). Non-destructive testing in civil engineering—A memorandum for teaching NDTCE at universities. *Civil Engineering Design, 7*(1), 49–60. https://doi.org/10.1002/cend.202400041

[4] Ji, H., Yang, H., Qi, H., & Liu, B. (2020). Survey and reflections on online teaching of "Non-destructive Testing Technology" during the COVID-19 pandemic. *Creative Education Studies, 8*, 1102.

[5] Ming, C., & Wang, W. (2025). Ideological and political education in Nondestructive Testing courses under the background of industry–education integration. *Educational Theory and Research, 3*(11), 172–174.

[6] Xiao, Q., Liu, Z., Yang, P., & Yang, L. (2024). Experimental design and practice of nondestructive testing for steel wire ropes based on magnetic flux leakage. *Experiment Science and Technology, 22*(1), 76–81.

[7] Ning, S., Zhao, G., Li, Q., & Wang, S. (2024). Case design for teaching innovation thinking course from the perspective of integrating professional and innovation education. *Creative Education Studies, 12*, 352. https://doi.org/10.12677/ces.2024.125294

[8] Yu, T., Chang, D., Wu, C., & Chen, M. (2024). Practice of course development for “Fundamentals of Intelligent Manufacturing Technology” in the Intelligent Manufacturing Engineering major. *Frontiers of Modern Education, 5*(2), 27–29.

[9] Zhang, C., Shan, X., & Han, T. (2025). Innovative teaching practices for mechanical engineering majors integrating optoelectronic information technology under the background of New Engineering Education. *Frontiers of Modern Education, 6*(3), 81–84.

[10] Hou, D., Zhao, J., Yu, H., & Qiao, X. (2024). Exploration and practice of teaching quality improvement methods for the course "Fundamentals of Non-Destructive Testing Technology" for international students. *Advances in Education, 14*, 932. https://doi.org/10.12677/ae.2024.144609

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