

Teaching innovation reform based on the "triple integration and triple linkage" model: a case study of the course "intelligent detection technology"

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Abstract. To address key challenges in "Intelligent Detection Technology"-inadequate practical connection, insufficient characteristic education outcomes, and lack of practical innovation-the authors constructed the "Triple Integration" initiative (integrating teaching content, adopting an O-AMAS-based blended teaching model, and combining university-enterprise collaboration with professional innovation) following a student-centered, problem-oriented, and continuous improvement philosophy. This achieved the "Triple Linkage" goal: linking the course closely to professional applications, characteristic education, and practical innovation. Practice shows the "Triple Integration and Triple Linkage" innovative model effectively mitigates core challenges, cultivates students' ability to apply intelligent detection methods for problem-solving, and provides a theoretical foundation and design ideas for subsequent practical design sessions.

Keywords: Emerging engineering; Fostering virtue through education, Two characteristics and one degree (TCOD), "Triple integration and triple linkage" innovative teaching model, Intelligent detection technology, O-AMAS teaching method.

1 Introduction

1.1 Basic course information

"Intelligent Detection Technology" is a professional foundational course offered to junior-year mechanical engineering students in the 6th semester, with a total of 44 class hours (including 8 class hours of experiments). This course covers a range of topics that blend diverse fields like detection technology, sensor technology, electrical engineering, and signal processing. It stands out for its strong foundational knowledge, practical engineering applications, and interdisciplinary approach.

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1.2 Key Challenges in Course Teaching

1.2.1 Insufficient In-depth Integration with Engineering Practice

Students' mathematical and physical foundations and cognitive abilities vary greatly. As a fundamental professional course, it should adapt to the individualized needs of students at different levels and address practical engineering problems in specialized fields. A critical challenge lies in breaking down the barriers between traditional disciplines, realizing the interdisciplinary integration of foundational and professional courses, aligning course teaching with information technology in the digital era, and embodying the 'Two Characteristics and One Degree (TCOD)'[1]-Higher-order Nature, Innovative Characteristics, and Appropriate Degree of Challenge.

1.2.2 Lack of In-depth Integration with Characteristic Education

Traditional course teaching focuses primarily on knowledge transmission and ability cultivation, with insufficient in-depth value guidance for students. How to leverage the educational characteristics of provincial-ministerial co-constructed local universities, explore the educational elements embedded in the course, and integrate value guidance into knowledge transmission and ability cultivation to achieve the organic combination of teaching and education has emerged as an urgent task.

1.2.3 Lack of In-depth Integration with Practical Innovation

In-class activities predominantly focus on lectures, exercises, and tests, which do not effectively engage students' learning interest or tap the full potential of the "Intelligent Detection Technology" course. Additionally, it is crucial to enhance practical connections with existing teaching resources, address real-world engineering challenges, and foster practical innovation.

The primary objective of this course is to fulfill the fundamental task of Fostering Virtue through Education (a core principle of Chinese higher education emphasizing moral cultivation as the foundation for talent development). By centering on the development of engineering application systems, the course seeks to achieve the organic integration of students' knowledge, abilities, and qualities, thereby enhancing their capabilities to solve complex engineering problems and fostering their higher-order thinking skills.

2. Innovative Design and Measures for Course Teaching

To address the long-standing challenges in teaching, the course team has adopted the "Triple Integration" initiative (integrating teaching content, adopting an O-AMAS-based blended teaching model[2], and integrating university-enterprise collaboration with professional innovation), which achieves the "Triple Linkage" goals of closely linking the course to practical application, characteristic education, and practical innovation, thereby comprehensively resolving the key teaching challenges (Fig. 1).

2.1 "Three-Dimensional Reconstruction" to Integrate Teaching Content and Form a Multi-Dimensional Knowledge Structure

Against the backdrop of "Emerging Engineering Disciplines and Fields (a core initiative of China's higher engineering education reform focusing on interdisciplinary integration, industrial demand alignment, and innovative talent cultivation)" [3] construction, the teaching plan is formulated in accordance with the university's professional construction requirements and the college's professional training program. The teaching syllabus is revised, and the teaching content is adjusted in a timely manner based on the needs of the profession's alignment with industry development. Teaching content is designed into three levels of difficulty: low, medium, and high. Three different teaching methods are employed: pre-class online self-study tasks; in-class offline face-to-face instruction + group discussion + case analysis; and post-class advanced modeling + innovative applications. The three-level goals of knowledge, ability, and value are infiltrated into each type and level of teaching content, forming a multi-dimensional three-dimensional content structure. This structure meets the needs of output-oriented professional talent training, ensures the integrity of the knowledge system, achieves the teaching objectives, and effectively addresses the teaching challenges of a single-structure teaching content and disconnection from professional applications.

2.1.1 Focusing on Frontiers and Feeding Teaching with Scientific Research to Enhance Course Depth

Specific measures are shown in Table 1.

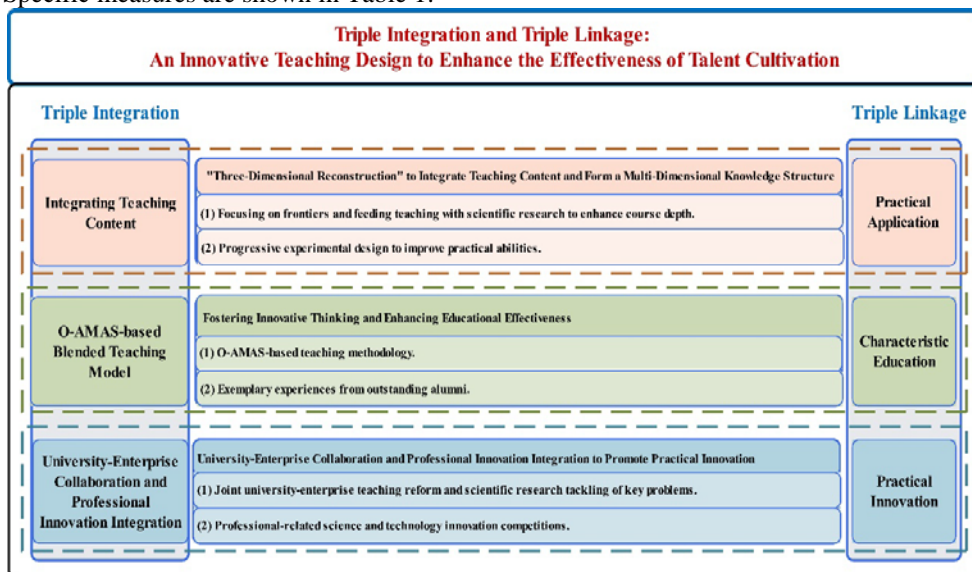


Fig. 1. Overall Plan of the " Triple Integration and Triple Linkage " Innovative Design.

2.1.2 Progressive Experimental Design to Improve Practical Abilities

On the basis of basic verification and comprehensive experiments, optional innovative experiments are added, such as MATLAB-based signal generation and spectrum analysis, NI ELVIS-based signal processing system design, and Arduino-based detection system design. The hierarchical experiments designed with the help of software and hardware

practice platforms related to the course (e.g., MATLAB data analysis software, NI ELVIS, and Arduino experimental development platforms) enable intuitive and vivid visual display and dynamic data acquisition and processing. Students not only understand the core idea of "dynamic detection" throughout the course but also realize that "reliable detection results" must be based on system stability. This fundamentally breaks through the limitations of "intuition", promotes students to see through phenomena to the essence, and reflects the TCOD of classroom teaching.

Table 1. Specific Implementation of Integrating Frontier Content and Scientific Research Achievements into Teaching.

No.	Measures	Content	Objectives
1	Introducing the process of major international scientific and technological innovations related to the course	Examples: eddy current effect, piezoelectric effect, the world's first radio telescope	Explain the causes and consequences behind scientific and technological innovations, guiding students to conduct preliminary scientific research.
2	Presenting major domestic and international cases of scientific misconduct or erroneous judgments	Example: the AM/FM debate.	Guiding students to consider the issue from multiple perspectives, such as technological development, economic interests, and society.
3	Integrating "Artificial Intelligence (AI)-related elements" into teaching [4]	Internet of Things: AI's data support partner. Metaverse: AI's application-carrying ecosystem. Large models + embodied intelligence: AI's core endogenous elements.	Further elaborating the fundamental role and promoting effect of sensors in these related elements.
4	Introducing teachers' scientific research achievement cases	Examples: Magnetic suspension bearings, long-distance line-structured light obstacle detection sensors, quadruped robot inspection, assistance for the elderly and disabled, etc.	To strengthen the exemplary role of teachers.

2.2 O-AMAS-based Blended Teaching Model: Fostering Innovative Thinking and Enhancing Educational Effectiveness

After years of accumulation, the course team has built a comprehensive platform resource. It has not only explored an O-AMAS-based blended teaching model that meets the needs of the university's talent training (Table 2) but also provided strong platform support and operational impetus for integrating teaching content, blending teaching models, and combining teaching with education [5].

2.2.1 O-AMAS-based Teaching Methodology

In the blended learning model, the online pre-study component replaces the conventional classroom lectures on basic knowledge, while the offline classroom instruction incorporates classroom group activities and discussions [6]. Students can independently acquire

fundamental and some intermediate-to-advanced concepts through online platforms. The offline instruction uses the O-AMAS teaching methodology, dedicating more time to discussion, reflection, and solving advanced problems, thus effectively implementing the curriculum reform.

Table 2. O-AMAS Teaching Method [2].

	Components	Specific Content
O-AMAS in the Classroom	Objectives	1. Knowledge transmission objectives 2. Ability cultivation objectives 3. Value shaping objectives
	Activation	1. Quickly engage students in the classroom 2. Stimulate brainstorming
	Multi-learning	Flipped classroom, Problem-Based Learning (PBL)
	Assessment	Combining multiple assessment methods
	Summary	1. Mind mapping 2. Exit ticket and ORID self-reflection

Note: ORID refers to Objective, Reflective, Interpretive, Decisional, a structured reflection method.

2.2.2 Exemplary Experiences from Outstanding Alumni

Exceptional alumni who completed the course were invited to create videos, detailing how they have utilized the course content in their professional endeavors. They used real-world case studies to inspire students' enthusiasm for innovation, demonstrating the exemplary role of these senior alumni and motivating them to innovate. These graduates included R&D leaders in leading companies in the machinery industry, key members of student satellite R&D teams, and recent graduates admitted to top universities for master's programs without entrance exams. They recounted their experiences, emphasizing the significance of the course and showcasing their achievements.

2.3 University-Enterprise Collaboration and Professional Innovation Integration to Promote Practical Innovation

2.3.1 Joint University-Enterprise Teaching Reform and Scientific Research Tackling of Key Problems

The team collaborates with leading enterprises in the industry chain, industry-specific enterprises, and high-tech enterprises in teaching reform and scientific research tackling. Through industry-university-research integration, project-driven practice [7], and innovation and entrepreneurship competitions, it provides students with rich practical resources and platforms, and constructs a "classroom-laboratory-enterprise" trinity practical teaching system.

In recent years, the team has tackled practical projects through university-enterprise cooperation and introduced teaching and research achievements into teaching, realizing in-depth industry-education integration. The transformation of project achievements into teaching cases not only helps cultivate students' practical project research capabilities but also improves their problem-solving abilities, ignites their enthusiasm for practical work, fosters their innovative spirit, and lays a solid foundation for their future professional growth.

2.3.2 Professional Field-Related Science and Technology Innovation Competitions

We invite experts from both inside and outside the university to deliver special lectures on robotics competitions, providing precise guidance for students to participate in academic competitions such as the International Youth Artificial Intelligence Competition and the Shandong Provincial College Student Intelligent Manufacturing Competition. This not only enables students to acquire experience and achievements in these competitions but also fosters their passion and confidence in innovation and entrepreneurship.

3. Diversified Assessment and Evaluation System

An assessment system has been developed that targets multiple objectives—focused on knowledge, abilities, and values—employs diversified evaluation methods (integrating quantitative-qualitative and formative-summative assessments), and involves multiple evaluation subjects (student self-evaluation, peer evaluation, and teacher evaluation). The implementation of diversified and multi-dimensional assessment has shifted the focus from merely assessing foundational knowledge to equally evaluating "foundational knowledge, practical application ability, and professional literacy." After years of reform, process-based assessment [8] now comprises 60% of the total course score.

In addition to conventional evaluations such as classroom performance, practical performance, and final examinations, several questionnaires have been designed with reference to Wuhan University's Curriculum Ideological and Political Teaching Evaluation Guidelines [9-10]. The improved evaluation system includes multiple dimensions such as theoretical knowledge assessment, practical skills operation, innovative project design, and personal literacy, ensuring the all-round development of students' abilities. Pre- and post-course questionnaires show that students' perceptions of critical thinking, learning self-efficacy, professional identity, and scientific spirit have all improved.

4. Reform Achievements and Promotion Value

4.1 Comprehensive Improvement in Student Learning Outcomes

Through a series of teaching reforms, the course's attractiveness has been enhanced, leading to improvements in student attendance, homework completion rates, and exam scores. Simultaneously, through school-based course evaluations, student satisfaction and recognition have steadily increased. For example, the author's course evaluation scores for the past three years were 94.35, 97.61, and 99.95, respectively. Furthermore, teachers' teaching enthusiasm and professional fulfillment have also been strengthened.

4.2 Enhancing Students' Practical Innovation Abilities

Students engage in teaching and research projects alongside curriculum team faculty, contributing to the publication of teaching and research papers or patents. They actively participate in professionally relevant competitions. In the past two years, students from the 2020 cohort and above formed over a dozen teams, winning more than 20 awards in competitions such as the International Youth Artificial Intelligence Competition and the Shandong Provincial College Student Intelligent Manufacturing Competition, demonstrating a significant improvement compared to the 1-3 awards per year before 2020, when curriculum reforms were not implemented.

Furthermore, based on laboratory equipment and scientific research achievements, students are guided to participate in voluntary science popularization activities [11], which not only exercises their expressive abilities but also enhances their awareness and ability to serve society with knowledge.

4.3 Significant Improvement of Teachers' Teaching and Research Levels

To keep abreast of the trends and development of educational reform, grasp the characteristics of students in the new era, improve teachers' educational capabilities, and pay attention to teachers' mental health, the team's teachers regularly engage in both domestic and international academic exchanges and training programs. In recent years, the team's teachers have won awards such as the "Second Prize in the Industry-Education Integration Competition of the Chinese Mechanical Engineering Society", "First and Second Prizes in the University-Level Teaching Innovation Competition", "First Prize in the University-Level Young Teachers' Teaching Competition", and "University-Level Young Teaching Experts".

4.4 Demonstration Role of Course Construction

The accomplishments in curriculum development have been implemented and promoted across the university in disciplines such as Mechanical Engineering, Vehicle Engineering, and Intelligent Manufacturing. The university's online courses receive over 200,000 visits annually. The Provincial-level Online Open Course [12] has attracted public learners including current students from 6 universities and graduates from 18 universities, with a cumulative enrollment of over 700 learners. The authors have been invited to deliver keynote speeches or participate in roundtable forums at multiple domestic and international conferences.

5. Conclusion

After several years of exploration and practice of the "Triple Integration and Triple Linkage" innovation, the course is gradually transforming from a traditional classroom to a smart classroom, from a knowledge-oriented classroom to a competency-oriented classroom, from an indoctrinative classroom to a practical classroom, and from a closed classroom to an open classroom. In future teaching, modern information technology should be more fully utilized to guide students with low activity and participation, and stimulate their enthusiasm for independent learning. Teaching reform and innovation need to be further refined, explored in depth, and expanded. By leveraging the advantages of the university-level first-class course, the concept of "awakening-empowerment-growth-success" should be adhered to in order to foster the comprehensive development of students.

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