Adult and Higher Education (2026)
Clausius Scientific Press, Canada

DOI: 10.23977/aduhe.2026.080207
ISSN 2523-5826 Vol. 8 Num. 2

Research on the Construction of Teaching Resources for Cultivating Intelligent Equipment Design Capability

Bo Hu*, Yuqiu Shi

College of Automation, Guangxi University of Science and Technology, Liuzhou 545006, Guangxi, China

**Corresponding Author*

Keywords: Intelligent Equipment Design; Teaching Resource Construction; Capstone Course; Blended Learning; Engineering Education

Abstract: The capability to design intelligent equipment is a core component of the comprehensive professional competence of engineering students majoring in automation, electrical, electronics, machinery, and instrumentation. At the current stage, the cultivation of this capability relies excessively on disciplinary competitions, leading to significant limitations in educational coverage. To address this, we propose exploring a capability cultivation path centered on optimizing the construction of informational teaching resources, based on the concept of Capstone Courses. Combining the existing shortcomings of current professional course systems and competition-driven education models, we establish a knowledge topological structure encompassing three major modules: mechanism design, information acquisition, and data processing. This integrates expansive teaching content into core professional courses such as system modeling and automatic control principles. Relying on iteratively upgraded blended teaching resources, we construct an autonomous learning system driven by "competition leadership and project-based learning," providing a systematic learning path for a wide range of students to independently enhance their engineering design capabilities after class. Research results indicate that this cultivation model can effectively bridge the gap between basic classroom teaching and the cultivation of advanced comprehensive engineering capabilities, offering a reference for the large-scale cultivation of students' practical innovation capabilities in the field of engineering education.

1. Introduction

The ability to design intelligent equipment comprehensively reflects the professional proficiency of engineering students majoring in automation, electrical engineering, electronics, mechanical engineering, and instrumentation. Independently completing the full design and debugging of complete sets of intelligent equipment is a crucial benchmark for evaluating engineering students' engineering design capabilities. Relevant engineering practical experience is also a core competency heavily scrutinized by employers during recruitment and by graduate schools during re-examination. Even if students cannot independently complete a full equipment R&D project during their time at university, upon entering the industry, equipment scheme design, installation, debugging, and maintenance are all routine tasks for engineers. The ability to design intelligent equipment directly impacts the job competency of frontline engineers. Therefore, cultivating intelligent equipment design capability is an indispensable and critical component of the engineering education system in engineering disciplines.

However, from the perspective of current teaching practices, singular classroom theory and basic practical instruction cannot support students in forming systematic intelligent equipment design capabilities, a problem particularly prominent in local engineering universities [1,2]. Currently, the cultivation of this ability in domestic universities primarily relies on various disciplinary competitions. Physical intelligent equipment prototypes have always been the most valuable entries in high-level disciplinary competitions such as the "Challenge Cup." However, the competition-based education model inherently suffers from a narrow audience. In recent years, domestic universities have continuously promoted the universalization of disciplinary competitions, but the popularization efforts have mainly focused on simulation-based competitions and small-scale production competitions like mathematical modeling and electronic design contests. Due to objective constraints such as funding, the energy of full-time faculty, and project R&D cycles, competitions involving the development of physical intelligent equipment can only accommodate a small number of students, and the proportion of students who ultimately possess independent equipment design capabilities is even lower. This creates a prominent pedagogical contradiction: the cultivation of intelligent equipment design capability heavily relies on niche physical competitions, while popularization efforts in general competitions cannot cover hardware R&D practical content [3,4]. Existing related research also indicates that the current practical teaching system in universities suffers from fragmented course knowledge and insufficient support for comprehensive design capabilities. While the competition-oriented elite training model yields outstanding educational results, it is difficult to adapt to regular, mass-oriented classroom teaching scenarios.

The aforementioned teaching pain points indicate that relying solely on disciplinary competitions cannot achieve the goal of cultivating engineering design capabilities for all students. Under the premise of maintaining the stability of the existing curriculum system, establishing a systematic extracurricular information-based teaching resource and providing standardized, closed-loop independent training channels for non-competing students is a direction worthy of deep cultivation in engineering education reform. Therefore, based on the actual teaching pain points of engineering majors, considering the construction of information-based teaching resources as an entry point to build an extracurricular capability cultivation ecosystem that adapts to the current talent training program may also provide a viable reference solution for practical teaching reforms in similar engineering disciplines.

2. Problems and Solutions in Cultivating Smart Equipment Design Capabilities

Smart equipment design falls under complex, high-level engineering capabilities. Compared to the single-structure design of traditional mechanical and electrical equipment, it demands higher levels of systemic engineering thinking and cross-curricular knowledge integration from students. Current university curricula adopt a modular breakdown model, with engineering design capability cultivation dispersed across different teaching stages, leading to insufficient cohesion between these stages. With the full implementation of engineering education professional accreditation, each course has established a quantitative assessment mechanism for teaching objective attainment. To ensure that assessment indicators are quantifiable and traceable, high-level, expandable teaching content is often not included in formal course teaching objectives due to the difficulty of precisely calculating its attainment. In-class teaching only focuses on foundational knowledge and basic practical skills, making it difficult to meet the advanced requirements of smart equipment system design. The lack of unified planning and systematic reinforcement for developing advanced capabilities across various teaching stages is a core reason for the generally weak comprehensive design capabilities of students.

At the same time, disciplinary competitions, which serve as a core vehicle for high-level practical education, are difficult to scale up. Smart equipment research and development competitions involve significantly higher costs for hardware consumables, experimental venues, and one-on-one guidance human resources compared to purely simulation-based competitions, making it impossible to replicate the widespread participation model of lightweight competitions. Some studies indicate that the insufficient supply of comprehensive, independent practical platforms and the lack of systematic engineering practice projects are major bottlenecks restricting the improvement of engineering students' comprehensive design capabilities [5]. Some universities have attempted to convert competition cases into in-class course projects, but constrained by fixed classroom hours and inherent course assessment systems, the effectiveness of teaching integration has not met expectations [6-8]. Furthermore, the knowledge points acquired by students in different courses are fragmented, lacking comprehensive engineering projects as a vehicle for knowledge integration, and single-point professional knowledge cannot be transformed into complete system design capabilities [9]. How to break down the educational barrier between foundational classroom teaching and elite disciplinary competitions, and establish an inclusive path for cultivating design capabilities for all students, has become an urgent problem to be solved in current engineering practical teaching.

Addressing the above teaching pain points, the following optimization ideas, adaptable to the existing teaching system, can be considered:

(1) Improving students' smart equipment design capabilities is an inevitable requirement for cultivating engineering talents, but the traditional competition-driven model is only suitable for cultivating top students and cannot be broadly implemented for all students.

(2) Therefore, there is no need for structural adjustments to the existing curriculum system or the course attainment evaluation mechanism. Instead, the focus can be on developing extracurricular teaching resources to compensate for the shortcomings in cultivating high-level capabilities.

(3) Specifically, establish a dedicated self-learning resource library based on an information-based teaching platform to provide clear, hierarchical learning paths for students' after-class self-study.

The core advantage of this approach is that it does not alter existing in-class teaching arrangements, does not increase the burden of classroom teaching, and relies on extracurricular "super-curriculum" extended resources to meet the individualized improvement needs of students who have additional capacity to learn. This resource-driven, student-initiated, and non-mandatory cultivation model not only avoids the rigid limitations of insufficient in-class hours but also caters to the differentiated capability development needs of students at various levels.

3. Ideas for Constructing Teaching Resources in the Cultivation of Intelligent Equipment Design Capability

The standardized assessment system for engineering education professional accreditation safeguards the baseline quality of foundational engineering talent cultivation. However, its fixed curriculum objectives and quantitative assessment rules struggle to accommodate the needs for fostering advanced extracurricular innovative design capabilities. After completing in-class foundational learning, students often only achieve basic course competency indicators, failing to reach the higher requirements of engineering design. Furthermore, autonomous extracurricular learning lacks systematic guidance, leading to low learning efficiency and fragmented knowledge. Given this educational reality, introducing the Capstone Course concept to restructure extracurricular teaching resources and break down knowledge barriers between courses can be considered.

A Capstone Course, also known as a Capstone Project, literally refers to the final cornerstone placed at the top of a building, symbolizing the ultimate integration and closure of a learning stage. In higher engineering education, a Capstone Course specifically denotes a comprehensive practical teaching segment where students, after completing most of their core professional courses, utilize a complete, real engineering project to integrate professional knowledge from across all academic stages and solve complex engineering problems. This teaching model emphasizes independent student inquiry, full-process engineering practice, and teamwork, effectively compensating for the shortcomings of fragmented classroom teaching and strengthening students' ability to solve complex engineering problems [10,11]. Therefore, it is well-suited to the cultivation of comprehensive design capabilities in engineering disciplines.

The construction of teaching resources will involve iterative optimization based on existing blended learning online resources within the institution. The core objective is the cultivation of students' advanced expansion capabilities, and this will guide the restructuring of online teaching resources and supporting learning plans around the complete design process of intelligent equipment. This differs from the traditional blended learning resources that solely serve in-class course assessments and aim to achieve basic course objectives. It requires supplementing advanced expansion content on top of existing online courseware and teaching videos, and restructuring the resource logic based on new learning plans. Expanded teaching resources can break the knowledge boundaries of a single course, helping students move beyond the basic teaching framework of individual courses, integrate knowledge across courses through extracurricular learning, and ultimately achieve the goal of cultivating intelligent equipment system design capabilities.

The expanded resources, built on the Capstone Course concept, move beyond the original positioning of online resources as supplementary content for in-class teaching. They form a complete learning system with independent learning logic and clear practical output objectives, providing stable content support for the cultivation of comprehensive engineering design capabilities.

4. Capstone Course-Based Learning Plan Design and Implementation

Integrating the core educational philosophy of Capstone Courses, a comprehensive and implementable extracurricular learning program is designed from three dimensions: knowledge system organization, online resource expansion, and the establishment of a long-term educational mechanism. This program is divided into three stages.

First, constructing a knowledge module topology map. Combining the complete research and development process of intelligent equipment with industry-specific job competency requirements, essential core knowledge for equipment design is organized. This knowledge is divided into three core modules: mechanism design, information collection and acquisition, and data processing. The content of these modules is precisely aligned with five core professional courses: System Modeling, Principles of Automatic Control, Error Theory, Intelligent Control, and Machine Vision. The topological map follows a progressive construction logic, moving from basic to comprehensive, and from single knowledge points to system integration: the mechanism design module connects with the kinematics and dynamics analysis content of the System Modeling course; the information collection and acquisition module integrates sensor detection and signal processing knowledge from Principles of Automatic Control, as well as measurement error analysis and compensation content from Error Theory; the data processing module aligns with intelligent algorithm fundamentals from Intelligent Control and image processing and target recognition content from Machine Vision. The map clearly defines the prerequisite, subsequent, and parallel learning relationships of each extended knowledge point, providing clear and intuitive guidance for students to independently plan their learning paths.

Second, expanding tiered blended learning resources. Based on the established learning plan, advanced extension courseware and instructional videos are supplemented to the existing blended online course resources. The core idea behind resource development is to independently separate in-class basic teaching resources from extracurricular extension resources. Simultaneously, content linkage is achieved through engineering case guidance, progressive questioning, and post-class extended thinking within the teaching content, gradually guiding students toward advanced content learning. This design breaks through the boundaries of basic knowledge corresponding to course attainment assessment, naturally extending learning content to ability enhancement sections beyond in-class assessment. Extension videos adopt a modular, short-duration, and project-oriented production format. Each teaching unit corresponds to a subdivided technical aspect of intelligent equipment design, accompanied by targeted post-class exercises and small modular design tasks, realizing the integration of learning with practical application and simultaneous learning and practice. Concurrently, leveraging the built-in functions of the online teaching platform, features such as knowledge point retrieval, learning progress annotation, and learning trajectory tracking are added to optimize the student's independent learning experience.

Third, establishing a tiered learning mechanism driven by "competition leadership and project orientation." After completing the iterative upgrade of teaching resources, a layered and progressive practical education system is established. With the high-level academic competitions such as "Challenge Cup", "Huichuan Cup", and the National College Students' Mechanical Engineering Innovation and Creativity Competition serving as the top-level guidance, and with graduation projects, professional course training, and school-level innovation competitions serving as the middle-level support, a gradient-based practical project system is constructed. By publishing design tasks of varying difficulty levels, from single-function module design to complete intelligent equipment system integration design, students are guided to use online extension resources to learn corresponding module knowledge and integrate basic knowledge learned in class to complete engineering design tasks. The entire practical process perfectly aligns with the core educational philosophy of Capstone Courses: students directly confront real engineering design problems, independently integrate professional knowledge from multiple courses, and independently complete the entire process of demand analysis, scheme design, prototype production, and system debugging. In the teaching process, the teacher's role transforms from a knowledge imparter to a learning guide and resource supporter, meeting students' personalized on-demand learning needs through extended teaching resources. Ultimately, a closed-loop learning ecosystem is formed, centered on cultivating intelligent equipment design capabilities, supported by informatized teaching resources, and driven by engineering projects, providing a replicable implementation framework for large-scale cultivation of comprehensive practical abilities in similar majors.

5. Conclusion

The ability to design intelligent equipment is a concentrated embodiment of the comprehensive professional quality of engineering students majoring in automation, electrical engineering, electronics, machinery, instrumentation, and other related fields. Addressing existing teaching problems such as a singular training path for this ability, insufficient coverage of talent cultivation through disciplinary competitions, and fragmented course knowledge, this paper proposes introducing the concept of a Capstone Course. It suggests three measures to broaden channels for all students to enhance their intelligent equipment design capabilities: building a knowledge module topology map, expanding blended learning resources, and establishing a layered project-driven learning mechanism. This exploration into teaching reform breaks through the limitations of talent cultivation caused by the traditional classroom teaching and elite disciplinary competition dichotomy. It offers new reform ideas and practical paradigms for the normalized and scaled cultivation of comprehensive design capabilities among engineering students in the context of emerging engineering education.

Acknowledgement

The 2023 Undergraduate Teaching Reform Project of Guangxi University of Science and Technology: Exploration and Practice of the Construction and Application of Information-Based Teaching Resources in the Cultivation of Intelligent Equipment Design Skills (No. 2023XJJG27).

References

[1] Pan Tianhong, Chen Quan, Song Yuqing, et al. Exploration of Practical Teaching Reform and Innovation Ability Cultivation in Engineering Disciplines – Relying on Internationalized Teaching of Innovative Engineering Design (SPIED) [J]. Education and Teaching Research, 2016, 30(9): 66-70.

[2] Lin Yousheng, He Qing, Tao Shi, et al. Teaching Reform and Practice of Comprehensive Professional Design Courses Aimed at Cultivating the Ability to Solve Complex Engineering Problems [J]. Science & Innovation, 2023, (3): 168-171+175.

[3] Lin Jingliang, Ou Weijun. Exploration of the Working Path for Disciplinary Competitions Based on "Broad-Deep" Dimensions – Taking the School of Engineering, Guangdong Ocean University as an Example [J]. Higher Education Journal, 2017, (22): 74-76.

[4] Zhang Chunsheng, Wang Jing, Su Zhen. The Value Implication, Predicament Representation, and Feasible Path of Disciplinary Competitions in Promoting Innovation and Entrepreneurship Education in Universities [J]. Educational Exploration, 2026, (1): 35-41.

[5] Yang Feng, Liu Jiang. Innovating the Teaching Model of "Fundamentals of Mechanical Design" Based on Real Projects [J]. China Power Education, 2026, (2): 94-96.

[6] Qi Qiang, Zhou Jianhua, Liu Ziji, et al. Reform and Innovation of the "Embedded System Design" Course Based on the New Engineering Concept [J]. Laboratory Research and Exploration, 2025, 44(6): 162-166.

[7] Guo Lin, Wang Shaopeng, Wang Baoyu, et al. Cultivation and Practice of Engineering Design Ability for Undergraduates in Local Universities [J]. Henan Chemical Industry, 2025, 42(10): 63-67.

[8] Jiang Junjie, Wang Yongbiao, Xiao Zhiling. Exploration of Teaching Reform for Mechanical Parts Mapping Course Based on Competition-Driven Approach [J]. Henan Education (Higher Education), 2026, (1): 85-87.

[9] Wang Yang, Hu Jiang, Li Jun. Exploration and Practice of Hive-PBL Teaching in PCB Design Course [J]. Journal of Zhejiang Wanli University, 2026, 39(2): 104-110.

[10] Zhao Jianfen, Liu Zhao, Dong Ji. Capstone Course Teaching Design and Practice Based on IEET Certification [J]. Agricultural Product Processing, 2023, (22): 149-152.

[11] Chen Xiaohu. Application of QC Circle Activities in Automotive Capstone Courses [J]. Automotive Practical Technology, 2022, 47(10): 126-129.