

Research on Project-Based Teaching Content Reconstruction for the Analog Electronics Course Based on Engineering Practice

Ning Dong^a, Yanyan Wu, Jia Ning, Bing Chen, Lisha Liu*

Industrial Training Centre, Shenzhen Polytechnic University, Shenzhen, 518055, China

^adongning@szpu.edu.cn

**Corresponding Author*

Keywords: Engineering practice; Analog electronics; Project-based teaching; Content reconstruction; Competency matrix

Abstract: To address the long-standing separation between theory learning and engineering practice in the Analog Electronics course for vocational undergraduates, this paper proposes a content reconstruction scheme based on typical engineering tasks. Following a closed loop of “industry-driven objectives, task-based content, workflow-guided teaching, and competency-mapping assessment”, the scheme constructs a three-level task system through dimensional reduction of industrial cases, and establishes a task-competency quantitative matrix to verify curriculum coverage and trigger dynamic early warnings. Teaching practice shows that the scheme significantly improves students’ engineering competence and learning outcomes, providing a replicable reconstruction model for practice-oriented electronics courses.

1. Introduction

Analog Electronics is a core course for electronic information majors, with strong practicality and prominent engineering attributes. However, traditional teaching generally adopts a model of “theory infusion + verification experiment”: students operate according to standard procedures, lacking comprehensive engineering tasks covering multiple knowledge points, without knowing “why it is done this way” or considering “what else could be done”, which results in weak mastery of knowledge points and a discontinuity in competency progression.

In response to the above problems, scholars at home and abroad have carried out extensive explorations of teaching reform. In terms of teaching models, Xia Huakang et al. [1] constructed an online–offline dual-track teaching framework based on an online platform, significantly improving students’ autonomous learning ability and knowledge internalization efficiency. In terms of the construction of virtual simulation resources, Shen Junhui et al. [2] explored the teaching of the Electrical and Electronic Technology course based on EDA technology, taking NI Multisim software as an example, effectively expanding the spatiotemporal boundaries of experimental teaching; however, virtual simulation can hardly replace the troubleshooting training in real circuit operation. In terms of course content reform, Yang Xinxiu et al. [3] reconstructed the Analog

Electronics course system to meet the needs of emerging engineering education, promoting the alignment of course content with industrial needs. Zhao Jing et al. [4] systematically explored the reform path and practical outcomes of the Analog Electronics course in the context of informatization. At the theoretical level, Mills and Treagust [5] earlier demonstrated the applicability of problem- or project-driven learning as a substitute for traditional lecture-based teaching in engineering education; Prince [6], through a systematic review of research on active learning, showed that project-based and problem-based learning can significantly improve learning outcomes; Bell [7] further pointed out that project-based learning is an effective way to cultivate key skills for the 21st century; review studies by Thomas [8], Kokotsaki et al. [9], and Hmelo-Silver [10] deepened the theoretical understanding of project-based learning from the perspectives of implementation conditions, influencing factors, and learning mechanisms.

Overall, existing reforms have achieved obvious results, but deep-seated limitations still remain: task design mostly stays at the level of module verification, lacks comprehensive engineering tasks covering multiple knowledge points, and has not fundamentally changed the situation in which course knowledge is organized according to textbook chapters and is disconnected from the logic of engineering tasks. The root cause lies in the teaching content itself. Therefore, with “engineering competency progression” as the main thread, this paper focuses on the reconstruction scheme of teaching content, so as to solve the chronic problem of “separation between learning and application”.

2. Research Approach and Overall Framework

This research follows a closed loop of “industry demand defines objectives—task carriers construct content—workflow guides teaching—competency mapping evaluates outcomes”. Among the three research directions of teaching content, teaching model, and evaluation mechanism, content is the core: only when teaching content first fits the talent cultivation positioning of vocational undergraduate education can the corresponding innovation of teaching models and reform of evaluation mechanisms proceed smoothly.

3. Teaching Content Reconstruction Scheme

3.1. Industry-Demand-Driven Objective Setting

A survey was conducted among smart manufacturing and consumer electronics manufacturing enterprises in Shenzhen. An advisory group composed of enterprise engineers (50%), vocational education experts (40%), and graduates (10%) was invited, and a core competency list was determined through two rounds of feedback: in the first round, open-ended questionnaires were used to collect high-frequency job tasks; in the second round, the importance of competency items was ranked on a 1–5 scale, and items with higher average scores were selected, covering job competencies such as analog circuit design, component selection, circuit debugging, fault diagnosis, and technical document writing. Furthermore, enterprise design requirement documents and maintenance manuals were analyzed to extract high-frequency skill points, forming a Competency–Knowledge Mapping Table as the baseline reference for course content reconstruction.

3.2. A Three-Level Task System of “Basic—Comprehensive—Innovative”

The chapter order of the textbook is broken, knowledge modules are reorganized according to engineering logic, teaching tasks converted from real enterprise cases are developed, and three engineering constraints—cost, power consumption, and size—are embedded to cultivate students’

engineering thinking. The three-level task system is shown in Table 1.

Table 1 Task level setting

Task level	Competency objectives	Typical task cases	Knowledge integration degree
Basic tasks	Instrument operation, unit circuit verification	Measurement of the static operating point of a common-emitter amplifier circuit	Single knowledge point
Comprehensive tasks	Multi-module joint debugging, troubleshooting	Fabrication of an adjustable DC power supply (rectification + filtering + voltage regulation)	Cross-chapter
Innovative tasks	Demand-driven design, constraint optimization	ECG signal detection and monitoring system	Cross-course

3.3. Pedagogical Transformation of Enterprise Cases

There is a huge gap between the real product cases of enterprises and teaching content. This paper adopts three adaptation approaches. First, case dimensionality reduction: industrial cases are appropriately simplified; for example, in the ECG signal detection circuit, some filtering stages are removed while the signal acquisition and amplification design is retained, and the entire system is divided into several modules to reduce learning difficulty. Second, fault implantation: typical engineering faults are set in tasks to train students' fault diagnosis ability. Third, task stratification: the same case is decomposed into basic tasks (single-point measurement), advanced tasks (multi-module joint debugging), and innovative tasks (circuit improvement), so as to achieve tiered teaching. Through the above "complexity coefficient" regulation model, enterprise engineers are invited to collaborate with full-time teachers to complete the pedagogical transformation of cases, solving the problem of balancing authenticity and operability in industrial case teaching.

3.4. Task–Competency Quantitative Matrix

A two-dimensional quantitative matrix is constructed, in which $\sqrt{\quad}$ marks indicate the coverage intensity of each teaching task over competency items such as debugging, design, documentation, and cost, as well as over the knowledge points of the course standard, so as to examine the degree to which the case combination covers the course standard and, accordingly, select a reasonable combination of 6–10 teaching tasks. When the case reserve is sufficient, differentiated case combinations can also be selected according to students' majors and learning conditions, so as to match the talent cultivation programs of different majors.

4. Implementation Path of Teaching Model and Evaluation Mechanism

In terms of the teaching model, teaching is organized by imitating the research and development process of enterprises, adopting three-stage training that combines virtual and real approaches: before class, virtual simulation and parameter optimization are carried out based on Proteus/Multisim; during class, modular experiment boxes are used for circuit construction and debugging; after class, students complete independent PCB design and hands-on practice, realizing a gradual transition from simulation to engineering products. In terms of the evaluation mechanism, a three-dimensional evaluation system covering operational norms, design ability, and engineering literacy is established, extending the task–competency matrix from a "content coverage verification"

tool to a “learning outcome assessment” tool: when a student’s coverage of a certain competency is insufficient, supplementary tasks are automatically triggered and issued, a personalized learning path is generated, and dynamic early warning is realized. In this way, demand analysis anchoring tasks, the dimensionality reduction model transforming cases, and the matrix monitoring competency coverage are interconnected, forming a closed-loop “industry–teaching–evaluation” research chain.

5. Application Cases and Outcomes

5.1. Application Cases

The core task carriers of this scheme have undergone preliminary verification in teaching practice, and two representative cases are as follows.

(1) Intelligent line-following car project (system integration dimension). As a comprehensive task carrier, this project covers sensor signal conditioning, operational amplifier applications, driver circuit design, multi-module joint debugging, and system-level troubleshooting, and requires students to complete the whole process of scheme design, simulation verification, physical construction, and performance testing in teams. The project integrates knowledge points scattered across multiple chapters, such as multi-stage amplifier circuits, comparators, and power driving, into a real engineering context. During the debugging process, students proactively revisit theories and revise their designs, effectively alleviating the problem of “separation between learning and application”. This case won the national first prize in the Third National Competition of Experimental Case Design for Electronic Information Majors’ Courses (RIGOL Cup) in 2023.

(2) ECG signal amplification circuit project (unit circuit dimension). This project is derived from the real signal chain of medical electronic products and is a typical weak-signal detection scenario. The task adopts dimensionality reduction transformation: the core design of signal acquisition and amplification is retained, some filtering stages are removed, and typical engineering faults such as power-line interference and electrode detachment are implanted. Students are required to complete component selection, gain allocation, common-mode rejection optimization, and noise suppression design, directly aligning with the analog circuit design and debugging competency requirements of enterprise positions. This case won the national second prize in the Fifth National Competition of Experimental Case Design for Electronic Information Majors’ Courses (RIGOL Cup) in 2025.

The two cases respectively verify the feasibility and effectiveness of the model of “driving theoretical teaching with real engineering projects” from the two dimensions of system integration and unit circuits, providing valuable practical samples and data support for the three-level task system proposed in this paper.

5.2. Implementation Outcomes

The project-based teaching pilot carried out based on the above task carriers has achieved outcomes in three aspects. First, students’ learning outcomes have improved significantly: driven by real tasks, students have shifted from “operating by steps” to “learning for problem solving”, with noticeably improved classroom participation and experimental report quality, a higher excellence rate in course assessment, and a significantly lower make-up examination rate, which is consistent with the research conclusions on the effectiveness of active and project-based learning [6,9-10]. Second, students’ engineering competence has gained industry recognition: relying on task-based training, students’ works directly align with the real needs of enterprises, reflecting the achievement of the “competency progression” objective. Third, the radiation effect of course construction has begun to emerge, and the concept of project-based teaching has been promoted and applied in

related courses.

6. Conclusion

The teaching content reconstruction scheme for the Analog Electronics course based on engineering practice proposed in this paper takes industrial demand as the logical starting point, three-level engineering tasks as the carriers, and the task-competency quantitative matrix as the evaluation link. Its effectiveness has been verified through two award-winning application cases, providing a systematic path for solving the problem of “separation between learning and application”. Follow-up research will be advanced in three stages—“industry alignment and content foundation, model verification and iterative optimization, comprehensive promotion and paradigm output”—producing research reports on project-based course reform, teaching research papers, and project-based textbooks, and forming a complete closed loop from theoretical exploration and practical verification to resource construction, so as to provide referable implementation examples for the teaching reform of electronics courses in similar institutions.

Acknowledgements

This article is an outcome of the project “Research on the Teaching Content Reconstruction Scheme of Analog Electronics Based on Engineering Practice” supported by “the Research Foundation of Shenzhen Polytechnic University.

References

- [1] Xia Huakang, Zha Xiaojing. (2025). *Practice of Online–Offline Blended Teaching in Analog Electronics*. *Creative Education Studies*, 13(3): 121-127.
- [2] Shen Junhui. (2010). *Exploration of the Teaching of Electrical and Electronic Technology Course Based on EDA Technology: Taking NI Multisim Software as an Example*. *Journal of Fujian Institute of Education*, 21(10): 74-76, 95.
- [3] Yang Xinxiu, Miao Jinchao, Ren Wenjie, et al. (2024). *Exploration of the Reform of the “Analog Electronics” Course Oriented to Emerging Engineering Education*. *South Agricultural Machinery*, 55(24): 158-161.
- [4] Zhao Jing, Zhang Runmei, Chen Zhong, et al. (2025). *Reform and Practice of “Analog Electronics” in the Context of Informatization*. *Electrical Technology*, 26(5): 72-78.
- [5] Mills J E, Treagust D F. (2003). *Engineering education—Is problem-based or project-based learning the answer?* *Australasian Journal of Engineering Education*, 15(1): 2-16.
- [6] Prince M. (2004). *Does active learning work? A review of the research*. *Journal of Engineering Education*, 93(3): 223-231.
- [7] Bell S. (2010). *Project-based learning for the 21st century: Skills for the future*. *The Clearing House*, 83(2): 39-43.
- [8] Thomas J W. (2000). *A review of research on project-based learning*. San Rafael, CA: The Autodesk Foundation.
- [9] Kokotsaki D, Menzies V, Wiggins A. (2016). *Project-based learning: A review of the literature*. *Improving Schools*, 19(3): 267-277.
- [10] Hmelo-Silver C E. (2004). *Problem-based learning: What and how do students learn?* *Educational Psychology Review*, 16(3): 235-266.