International Educational Research; Vol. 8, No. 1; 2025
ISSN 2576-3059 E-ISSN 2576-3067
https://doi.org/10.30560/ier.v8n1p74

# Teaching Reform and Practice of Digital Circuit Course Based on Hybrid Teaching Model

Xiaofei Deng[1], Weihong Cheng[1], Yi Zuo[1], Xian Zhang[1] & Guangya Huang[2]

[1] School of Information Technology and Management, Hunan University of Finance and Economics, China

[2] School of Communication and Electronic Engineering, Jishou University, Jishou, China

Correspondence: Xiaofei Deng, School of Information Technology and Management, Hunan University of Finance and Economics, Changsha, China. E-mail: xiaofei0228@163.com

Received: January 19, 2025; Accepted: February 25, 2025; Published: February 27, 2025

**Abstract**

In response to the persistent disconnection between theory and practice in traditional digital circuit courses, coupled with insufficient development of students' engineering competencies, a teaching reform has been implemented. The reform entails the reconstruction of the instructional design, practical sessions, and assessment system of the digital circuit course, achieved through the integration of theory and practice and the implementation of a hybrid online-offline teaching model. The teaching outcomes after the reform have shown remarkable progress, with an increase of 6.97% in the average score of students, and a 45% surge in competition awards at provincial and national levels. Furthermore, the new teaching mode has markedly enhanced students' logical thinking ability, engineering practice ability and innovation consciousness.

**Keywords:** digital circuit, integrated teaching of theory and practice, hybrid online-offline teaching, teaching reform

## 1. Introduction

As a core foundational hardware course for majors such as Electronic Information, Computer Science, Automation, and related disciplines, the significance of Digital Circuits is self-evident. How to enhance its teaching effectiveness has become a pressing issue of current concern [1-2]. Digital Circuits aims to cultivate students' key competencies in modern digital system design, and its course content provides essential methodological and practical foundations in hardware design for subsequent courses such as Computer Organization and Design, Embedded Systems and Applications, and Microcomputer Principles [2-3].

For engineering discipline courses, it is imperative to adhere to the principles of student-centeredness, outcome-orientation, and continuous improvement, relentlessly enhancing students' learning experience and outcomes, while resolutely avoiding superficial labeling or disjointed practices.

## 2. Approaches to Digital Circuits Teaching Reform

In traditional digital circuits instruction, teachers predominantly focus on lecturing theoretical knowledge in the classroom. While this method allows instructors to fully control the teaching process and deliver content systematically, it inherently fosters passive knowledge acquisition among students. Attentive learners may rapidly develop a structured understanding, whereas those with weaker foundations often struggle to keep pace, resulting in a pronounced cognitive differentiation effect within the class [4]. International engineering education research corroborates this, demonstrating that knowledge retention rates under traditional lecture-based models are 55 percentage points lower compared to active learning modalities [5].

As a highly practice-oriented course, Digital Circuits not only deepens the theoretical understanding through hands-on activities but also enhances practical skills. The deep integration of theory and practice allows abstract concepts to be immediately reinforced via in-class operational exercises, significantly improving student engagement and classroom efficiency. This approach ensures continuous training in advanced digital circuit design methodologies throughout the course [6]. To support this, the School of Information Technology and Management at Hunan University of Finance and Economics has established the Hunan Provincial Demonstration Center for Practical Education.

The center is equipped with 26 sets of Seewo Smart Interactive Blackboards and Smart Electrotechnical-Electronic Training Platforms, accommodating at least 52 students per session for simultaneous theoretical learning and practical training. These platforms feature three dedicated modules: circuit analysis, analog circuits, and digital circuits. Additionally, they incorporate a remote microprocessor application development experimental platform, effectively resolving conflicts between limited lab access and student scheduling demands.

Supported by management software and virtual-physical hybrid operation systems, the online experimental platform enables students to conduct experiments and innovate designs at anytime and anywhere, providing robust support for iterative "learning-by-doing" cycles. Within this center, students master digital circuit theories while completing diverse experiments, breaking free from traditional classroom constraints. This facilitates immediate assimilation of abstract concepts, stimulates learning motivation, and substantially elevates pedagogical outcomes.

Learning interest serves as the prerequisite for intellectual growth. Educational psychology research confirms that learning interest activates the dopamine reward mechanism in the prefrontal cortex, not only extending learners' sustained attention span, but more crucially, fostering stable cognitive drive. This intrinsic motivation empowers learners to overcome the "plateau effect" in knowledge acquisition, enabling a transition from rote memorization to meaningful knowledge construction [7-8]. Any knowledge failing to spark learners' interest risks reducing instruction to a laborious and uninspiring process [9].

Therefore, educators should prioritize systematically cultivating students' disciplinary interest ecosystems. For instance, when teaching combinational logic circuits, instructors could adopt smart home security systems as project-based learning frameworks. By challenging students to optimize real-world engineering problems like "reducing false trigger rates in fingerprint recognition", curiosity is naturally ignited. This approach stimulates autonomous exploration of Karnaugh map simplification and race hazard phenomena, followed by hands-on circuit optimization using 74LS series chips (e.g., 74LS08 AND gates and 74LS32 OR gates). Such contextualized practice effectively transforms abstract theories into tangible problem-solving experiences, thereby amplifying students' enthusiasm for applied learning.

## 3. Teaching Reform Model Implementation

Building upon established pedagogical practices from peer institutions [10], this initiative implements an integrated theory-practice approach coupled with a blended online-offline instructional model to reengineer the digital circuits course. The blended teaching framework is illustrated in Figure 1.

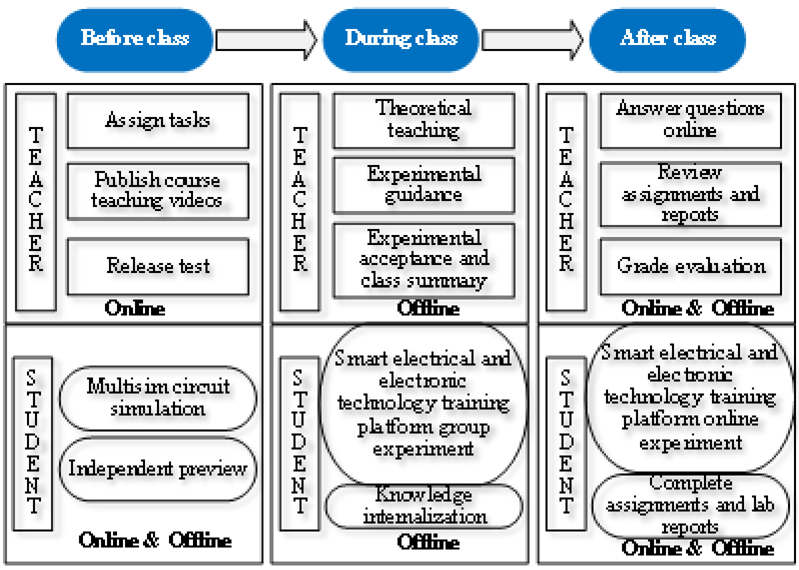


Figure 1. Hybrid teaching framework

### *3.1 Before Class*

Under the blended learning framework, the course team has developed a digital teaching resource system on the Chaoxing Fanya Platform. This system comprises diverse formats including micro-lecture videos with an average duration of 8 minutes, interactive simulation experiments based on Multisim, and knowledge graph-guided diagrams. These resources enable students to access course materials anytime and anywhere via the mobile Xuexitong app, allowing them to maximize fragmented time and significantly enhance learning efficiency.

Teachers distribute pre-class learning tasks to the course group of QQ or Xuexitong app before lessons. Utilizing the embedded learning behavior analysis module in the Chaoxing Fanya Platform, they monitor students' pre-class preparation in real-time by tracking key metrics: When the completion rate of prepare lessons beforehand falls below the threshold (target value ≥85%), automatic reminders are triggered to students. Additionally, based on statistical data showing error rates exceeding 40% on specific knowledge points (e.g., "methods for eliminating race hazards"), instructors dynamically adjust the teaching priorities in class.

### *3.2 During Class*

The instruction adopts a combined approach of blackboard writing and multimedia presentations. Circuit diagrams are displayed via slides, accompanied by logical relationship analysis to ensure students grasp the underlying principles. Concurrently, the Seewo Smart Interactive Blackboard is utilized to demonstrate circuit design processes through real-time boardwork, enabling students to both comprehend theoretical foundations and actively engage in design iterations. This methodology transforms static, abstract schematics into intuitive physical interface representations, thereby concretizing and visualizing textbook knowledge [11].

After completing circuit diagrams, instructors guide students to connect each wire individually on the Smart Electrical & Electronic Training Platform. This wire-by-wire immersion in logic circuit diagrams compels students to scrutinize schematics meticulously and deeply internalize circuit operational principles. Such hands-on methodology not only bridges theoretical knowledge with practical implementation, but also injects vitality into the learning process. By transforming abstract concepts into tangible wire connections, students develop passion for exploratory circuit design and achieve authentic knowledge-to-practice conversion.[6].

Throughout the instructional process, iterative interactions are emphasized through heuristic and case-based teaching methods, with intentional integration of ideological and political education elements. Students' experimental outcomes undergo rigorous review, showcase, and analysis to achieve enhancement, application, and extension of key and challenging concepts. Finally, instructors conclude the session with a structured summary, guiding students to reflect on and continuously refine their learning processes, thereby fostering the progressive deepening and advancement of knowledge and skills.

### *3.3 After Class*

Students log in to the Smart Electrotechnical-Electronic Online Training Platform to conduct experimental operations again. The platform offers an intuitive operational interface and real-time feedback functionality, enabling students to better grasp experimental principles and reinforce practical skills. Upon completing the experiments, they submit their lab reports online.

The course team utilizes the Xuexitong app to address student inquiries and resolve difficulties encountered during the learning process. Against the backdrop of engineering education accreditation, the team has systematically optimized the grading framework for online homework and lab reports.

The Chaoxing Fanya Platform automates the grading of objective questions to rapidly quantify mastery of foundational knowledge, while incorporating learning attitude metrics such as timeliness of submission and revision iterations into assessments. For lab report evaluation, the process-oriented approach has been enhanced: students are required to upload video clips of critical operational steps (e.g., oscilloscope calibration processes) to enable traceability verification of experimental data. At the same time, the teacher will comprehensively evaluate the experimental results according to the performance of students in all aspects of the experiment preview, operation process, report writing and problem solving, so as to ensure the comprehensiveness and objectivity of the evaluation [12].

## 4. Diversified Assessment System

Previously, the assessment of this course is based on the weighted calculation of ordinary scores and final exam scores, the final exam accounts for a larger proportion, and the ordinary scores are mainly composed of homework completion and attendance records. Due to the strong practical nature of the digital circuit course, many contents such as sequential logic circuit can be better understood through simulation and experiment. And the existing assessment method is difficult to fully reflect the learning effect. To this end, the course team divide the students into groups and assign tasks, which require the design of the circuit using the hands-on simulation and experimental verification. Then each group sends a representative to demonstrate and explain the circuit principle after completion. This process takes into account the usual grades, which not only enriches the classroom form and improves the teaching content, but also cultivates students' thinking, cooperation and practical abilities. Moreover, it helps teachers grasp students' learning situation more clearly and comprehensively evaluate their performance [13].

With the advancement of the professional certification of engineering education, the course team has built a diversified assessment system covering the whole process of learning, and strengthened the standardized quantification of process assessment and assessment indicators [4,14]. Relying on the course teaching reform, it realizes the process evaluation of students' learning attitude and basic knowledge through the attendance records, in-class quizzes and online homework carried out by the Chaoxing Fanya Platform. And The assessment system evaluates students' comprehensive design competence, implementation skills, and communication & collaboration capabilities through a tripartite structure: simulation experiment, offline experiment, and online experiment [9]. The assessment framework has been restructured with revised weightings: process evaluation now accounts for 50% of the total score, while the final examination constitutes the remaining 50%. The specific assessment system is shown in Table 1.

Table 1. Diversified assessment system for the digital circuit course

| | Assessment items and proportion | Assessment content | evaluator |
|---|---|---|---|
| Process evaluation | Attendance records (10%) | Learning attitude | Teacher evaluation |
| | In-class quizzes (10%) | Understand and master the correctness of knowledge points | System evaluation |
| | Homework (5%) | Analyze the correctness of problem solving | Teacher evaluation |
| Practical ability evaluation | Simulation experiment (5%) | Ability to analyze experimental data | Teacher evaluation |
| | Offline experiment (10%) | Demonstrate defense performance | Peer evaluation (20%) & Teacher evaluation (80%) |
| | Online experiment (10%) | Document report quality | Teacher evaluation |
| Summative evaluation | Final examination (50%) | Ability to understand, calculate, analyze and design | Teacher evaluation |

## 5. Effect of Teaching Reform

The teaching reform of digital circuit courses in our school is mainly reflected in online and offline teaching links and theoretical and practical teaching links, and has been fully implemented for computer science and technology undergraduates of grade 2022. The teaching effect of the course reform has been significantly verified by the student's score of the course, course evaluation, and students' participation in discipline competitions.

The course assessment results of the past two years are shown in Table 2. As illustrated in Table 2, the excellent and good rate of students (exceeding 80 points) has steadily increased from 44.13% in grade 2021 to 59.21% in grade 2022, and the average score has increased by 6.97%, which indicates that students are more and more active in learning digital circuit courses and the teaching effect is getting better and better.

Table 2. The score distribution of students in the digital circuit course

| Grade | 0-59 (%) | 60-69 (%) | 70-79 (%) | 80-89 (%) | 90-99 (%) | Average score (points) |
|---|---|---|---|---|---|---|
| Grade 2022 | 2.13 | 9.71 | 28.95 | 39.85 | 19.36 | 80.93 |
| Grade 2021 | 7.29 | 6.57 | 42.01 | 30.03 | 14.10 | 75.66 |

Our digital circuit course in the Chaoxing Fanya Platform have been widely praised. The evaluation pointed out that the course content is rich, and the explanation is detailed and easy to understand. Furthermore, it is noteworthy that the majority of students believe this course effectively enhances student engagement. And the teaching process is lively, engaging, and captivating, with a strong emphasis on developing students' practical skills.

Following the teaching reforms, computer science and technology undergraduates of grade 2022 have demonstrated growing enthusiasm in participating in national competitions such as the National Undergraduate Electronics Design Contest, China Collegiate Programming Contest, and National College Competition on Internet of Things, among others. They secured 42 provincial-level or higher awards, marking a 45% increase from 23 awards in the previous academic year. These outcomes substantiate significant improvements in students' practical competencies and innovative capabilities [15].

## 6. Conclusion

Our university uses a hybrid teaching mode of online and offline in the teaching of digital circuit courses, including the use of Xuexitong app for pre-class preparation, the conduction of Multisim software for simulation experiments, the combination of offline theoretical teaching and practical training operation, and the knowledge expansion through online experimental platform. The implementation of this teaching mode has yielded remarkable teaching outcomes.

Through continuous exploration and refinement, the course team has developed a distinctive practical teaching path in the reform of digital circuit teaching. Interactive methods such as group discussions and team collaborations encourage students to cooperatively solve problems in practice, while the online experimental platform reinforces and extends their knowledge, boosting learning engagement and motivation. This teaching model not only effectively supports theoretical teaching, but also greatly improves students' practical ability and innovation consciousness. It stimulates their enthusiasm for learning and creative drive, helping them cultivate professional skills in hardware system design while strengthening multifaceted competencies including the team cooperation, self-directed learning, and problem-solving ability.

**Acknowledgments**

This research was co-funded by General Project of Teaching Reform Research in Regular Higher Education Institutions of Hunan Province (HNJG-20221242), and the Key Project of Teaching Reform Research in Regular Higher Education Institutions of Hunan Province (HNJG-20220185, HNJG-20231362, HNJG-20230682, 202401001660).

## References

[1] Dong, X., Lan, J., Huang, H., et al. (2024). Course reform and practice of "Digital Circuit and Logic Design". *Journal of Electrical and Electronic Teaching, 46*(02), 77-80.

[2] Ma, X., & Ran, X. (2022). Exploration of new engineering digital logic course reform based on Logisim. *Computer Knowledge and Technology, 18*(16), 155-157. https://doi.org/10.14004/j.cnki.ckt.2022.1083

[3] Yang, L., Si, G., Wang, C., et al. (2025). Experimental teaching design and application of computer composition principle based on cognitive load theory. *Laboratory Research and Exploration, 1*-5. Retrieved January 24, 2025, from http://kns.cnki.net/kcms/detail/31.1707.t.20250117.1624.032.html

[4] Li, X., Zhou, W., Min, L., et al. (2024). Exploration and practice of hierarchical teaching model based on flipped classroom. *Journal of Electrical and Electronic Teaching, 46*(05), 10-14.

[5] Crawley, E. F., Malmqvist, J., Lucas, W. A., et al. (2022). The CDIO syllabus v2.0: An updated statement of goals for engineering education. Retrieved December 1, 2022, from http://www.cdio.org/files/project/file/cdio_syllabus_v2.pdf

[6] Li, Y. (2023). Design and application of "Digital Electronic Technology Foundation" MOOC. *Journal of Electrical and Electronic Teaching, 45*(1), 128-132.

[7] Cong, L. (1999). Arouse learning motivation and cultivate learning interest. *Journal of Shenyang Institute of Education, (S1)*, 49-50.

[8] Pintrich, P. R. (2003). A motivational science perspective on the role of student motivation in learning and teaching contexts. *Journal of Educational Psychology, 95*, 667-686. https://doi.org/10.1037/0022-0663.95.4.667

[9] Zhang, F., Yan, X., & Li, W. (2021). Research on the teaching reform of "Digital Circuit" course integrating CDIO mode and flipped classroom under the background of new engineering. *Chinese Education Informatization, (18)*, 69-72.

[10] Lu, P., Zhang, L., Shao, W., et al. (2023). Digital logic experimental teaching reform for training engineering practical ability. *Computer Education, (10)*, 87-91. https://doi.org/10.16512/j.cnki.jsjjy.2023.10.042

[11] Liu, L. (2022). Discussion on the teaching reform of "Digital Circuit and Logic Design" course. *Industrial and Information Education, (2)*, 4.

[12] Lin, M., Zheng, P., & You, B. (2024). *Exploration and practice of engineering education certification for electronic information majors*. Beijing: Chemical Industry Press.

[13] Wen, J., & Zhang, Q. (2022). Ideological and political exploration of "Digital Circuit and Logic Design" course. *Science and Education Guide, (02)*, 97-99. https://doi.org/10.16400/j.cnki.kjdk.2022.02.031

[14] Chen, J., Xiong, L., Zhou, J., et al. (2023). Mixed teaching reform and practice of "Digital Electronic Technology" course based on pocket lab. *Industrial and Information Education, (02)*, 45-49.

[15] Wang, W., & Pan, X. (2024). Exploration and practice of digital circuit experiment teaching reform. *Computer Education, (06)*, 162-166. https://doi.org/10.16512/j.cnki.jsjjy.2024.06.030