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The Course Reform Practice of "Electronic Circuit Design" in Higher Vocational Colleges Based on the Training of Engineering Practice Innovation Ability

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Abstract. To enhance students' proficiency in solving engineering problems, foster their awareness of innovation and entrepreneurship, the main focus is on developing skills in understanding, drawing, and innovating drawings. This approach closely aligns with the advancements in science and technology as well as industrial changes by incorporating real-world PCB design engineering cases, PCB process specifications requirements, and electronic product design. Through a blended learning approach combining online and offline teaching methods, we aim to integrate standards and expand engineering practice cases to establish a 'three-level, four-ability' model for practical training and innovation. Furthermore, we strive to instill an entrepreneurial mindset along with high standards of craftsmanship throughout the teaching implementation. Ultimately, this comprehensive approach effectively enhances students' ability to apply theoretical knowledge into practice while solving practical engineering problems and fostering innovative thinking. It lays a solid foundation for nurturing talents specialized in circuit board design."

Keywords. PCB Design, Engineering practice, Innovation, Electronic circuit design

1 Introduction

In the context of emerging productive forces, there is an urgent need to expedite the cultivation of novel productive forces and establish a new paradigm for workforce development. This necessitates not only the training of scientific research talents equipped with the capacity to generate innovative productive forces but also demands a substantial influx of applied talents proficient in leveraging cutting-edge production materials. Hence, it underscores the paramount importance of fostering a culture of innovation in education and promoting engineering applications [1].

"Electronic Circuit Design" is a pivotal course offered in higher vocational colleges that integrates schematic drawing, PCB design, circuit simulation, and circuit

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design with the aim to equip students with skills to transform electronic products into tangible objects. This course boasts strong technological foundations, interdisciplinary knowledge integration, and evident comprehensive practicality. However, current teaching methods primarily focus on students' proficiency in using drawing software while neglecting the feasibility and rationality aspects related to physical works involved in PCB design. Consequently, there exists a gap between circuit design and practical application ability which hinders the cultivation of students' innovative consciousness as well as their improvement in engineering practice ability.

In order to align this course more closely with the requirements for PCB engineers, hardware engineers, and positions engaged in circuit design; typical engineering practice cases combining analog electronics, digital circuits, hardware components selection along with software integration are introduced. Based on product development processes such as drawing creation, PCB designing & fabrication process control techniques including component selection criteria determination through welding practices followed by whole machine debugging procedures; The training concept of innovative and applied talents will be integrated into the advanced innovation ability training of "understanding map, drawing and innovation map"[2]. How to strengthen students' ability to solve practical engineering problems, strengthen students' ability to combine theory with practice, enhance their awareness of innovation and entrepreneurship, and cultivate highly skilled people with national feelings, the pursuit of excellence and excellence are new demands and new challenges for automation and electronic information majors.

2 Based on engineering case-oriented teaching design, we construct a curriculum system that cultivates practical innovation abilities through the "three levels and four capabilities"

Aiming at the pain points in the implementation of the traditional teaching of "electronic circuit design", taking the training of students' practical ability and double innovation ability as the main line. The curriculum reform focuses on two key aspects: 1) enhancing technical skills in EDA drawing software, and 2) broadening students' understanding of electronic circuit theory and design. This approach aims to develop students' abilities in graphical interpretation, drawing, circuit design, and product innovation. The cultivation of the 'four abilities' encompasses not only subject knowledge, but also entails fostering a sense of innovation, engineering design expertise, bridging the gap between theory and engineering practice, and instilling an entrepreneurial mindset [3].

2.1 Revise the teaching training objectives based on the practical application and innovative capabilities of "three levels and four abilities"

"Electronic Circuit Design" is a crucial course in higher vocational colleges aimed at cultivating technical talents for PCB design of electronic products and enhancing students' overall professional competence. The course design integrates PCB design specifications, circuit design principles, and product innovation knowledge structure with the teaching goal of circuit designing and manufacturing. By connecting schematic drawing, circuit component selection, PCB design, product assembly, and debugging instruction to the process of electronic product development in accordance with industry standards, students are trained to possess an engineering practice innovation ability that encompasses understanding drawings as well as creating innovative designs.

2.2 In light of the new quality productivity and the adjustment in industrial demand for talent, the course "Electronic Circuit Design" will align students' vocational core competence with industry requirements

The revision of teaching content will primarily focus on enhancing practical double creation ability through the "three levels and four abilities" framework. Specifically, attention should be given to the following core competencies:

(1) Image recognition capability: This course is scheduled for the third semester when students have already acquired basic knowledge in analog and digital electricity as well as electrical engineering. They possess skills in analyzing circuit schematic diagrams and manually drawing circuit diagrams but lack experience using EDA drawing software or understanding PCB design concepts. Therefore, the first two chapters of this course aim to familiarize students with drawing software and teach them basic operations.

(2) Drawing capability: The course necessitates students to possess a high level of operational proficiency and demonstrate expertise in utilizing EDA drawing software. Presently, the prevalent instructional software encompasses Altium Designer and domestic Lichuang drawing software. Additionally, students are unfamiliar with PCB design processes and industry standards. To address these gaps, two chapters should be dedicated to acquainting students with PCB design rules and operational methods so that they can effectively carry out software operations, complete PCB designs related to circuitry, and generate output files accordingly.

(3) Circuit design capability: The course encompasses a wide range of interdisciplinary knowledge to enhance students' problem-solving skills in engineering practice. By introducing practical cases based on the physical production of electronic products, theoretical drawings are transformed into tangible products, bridging the gap between theory and practice. Therefore, when designing the teaching content, it is essential to simulate typical electronics cases such as Bitu RC filter, DC regulated power supply, and voice-controlled light. This enables students to grasp circuit principles and become familiar with the circuit production process. Subsequently, digital circuits are designed based on representative cases to consolidate students' understanding of digital knowledge and acquaint them with PCB design rules for digital circuits. Finally, this course connects with "single-chip microcomputer application technology" and "embedded technology" courses by exploring hardware composition and circuit production through a typical case involving single-chip microcomputer minimum system and learning board design.

(4) Electronic product innovation capability: To cultivate students' innovation ability, they are required to carry out product innovation based on given themes and reference circuits (e.g., hardware innovation and functional innovation of single-chip microcomputer learning board). The final assessment includes a teaching segment where students can choose their preferred circuit related to the designated theme for schematic innovation or PCB layout innovation in terms of circuit production. This aims at fostering students' abilities in drawing diagrams, designing circuits, and promoting innovative thinking.

Set the course based on 'posts', clarify the core competencies required for circuit hardware and PCB design positions, and develop the 'four abilities' career based on project-based learning. The teaching content of this course is presented in Table 1.

Table 1: The teaching content of this course

number	Main teaching project	Project task	Knowledge content and requirements	Period
1	Resistor–capacitor circuit	Task 1: Install Altium Designer and learn its history Task 2: Create a new RC filter project file Task 3: Using the AD menu	1. Acknowledge EDA and PCB 2.Altium Designer drawing environment setup 3. Create, open and delete simple projects	8
2	Cycle light circuit design	Task 1: Multisim simulation design Task 2: Place wires and buses Task 3: Draw the title bar of the drawing Task 4: AD schematic component library Task 5: Schematic drawing of the circuit of cyclic color lights	1. Setup of schematic drawings and use of drawing tools 2.Schematic creation and component placement 3. Basic Settings of schematic drawings 4. Schematic graphic objects and their editing 5. Design of schematic title bar 6. Schematic drawing	8
3	PCB design of voice-controlled frequency conversion circuit	Task 1: voice-controlled frequency conversion circuit schematic drawing Task 2: PCB design of voice-controlled frequency conversion circuit Task 3: PCB rule design of voice-controlled frequency conversion circuit Task 4: PCB generation of voice-controlled frequency conversion circuit common fault analysis Task 5: NE555P component package of voice-controlled frequency conversion circuit Task 6: Design of the integrated library	1. Drawing of analog component integration library, schematic library and PCB package library 2. PCB board creation and design import, PCB engineering compilation 3.PCB component packaging wizard 4. Manually encapsulate 5.PCB board planning and component layout 6.PCB automatic and manual wiring 7 Package and working principle of common components 8. Check PCB rules and generate reports	8
4	Production line product automatic counting device	Task 1: Principle of automatic counting device for production line products Task 2: Multisim simulation and schematic design Task 3: PCB drawing design Task 4: Welding and circuit debugging and assessment	1. Circuit design process of automatic counting device of production line 2. Schematic design and PCB drawing of automatic counting device for production line 3. Solutions to practical problems in circuit engineering	12
5	51 MCU learning board design and production	Task 1: Copy the component library of the learning version of the single chip microcomputer Task 2: Schematic diagram of single-chip learning version Task 3: single-chip learning version of the component package library Task 4: PCB design of single-chip learning version	1.51 SCM learning board design principle and method 2. MCU learning board PCB board design 3.PCB design file output 4. Component package and component library of digital chip 5.PCB circuit two-layer board design 6.3D Model diagram import 7. Design of hierarchical schematic diagram	12
6	STM32 minimal system design	Task 1: STM32 minimum system component selection Task 2: Chip component schematic drawing Task 3: Patch component package library drawing Task 4: STM32 minimum system PCB design	1. The principle of STM32 minimum system and the plotting method of patch components 2. STM32 minimum system PCB board design 3. STM32 minimum system 4-layer board design 4. STM32 PCB production, patch welding and debugging	12

3 Construction of engineering practice cases of entrepreneurship and innovation practice teaching methods to provide direction for "entrepreneurship and innovation" education

Focusing on the training of students' practical ability and mass innovation ability, the teaching mode of "teaching + skill competition + mass innovation project" has been established. Combined with the requirements of "post class competition certificate", the results-oriented concept has been strengthened, and the mixed teaching of online and offline has been constructed. Through teaching, students can finally achieve the step improvement of engineering practice and innovation ability of "understanding drawing, drawing and innovation drawing"[4].

3.1 Set lessons by "post", test learning by "competition", combine teaching and competition, and effectively enhance students' interest in drawing

According to the needs of the post, the competition to promote learning, provincial skills competition, national college students electronic design competition, "Internet +" college students innovation and entrepreneurship competition, "Blue Bridge Cup" EDA design and development competition as the starting point, the course related competition questions, PCB specification requirements and innovation and creativity into the curriculum. Make the teaching technical, professional, comprehensive and practical. Set up different theme learning groups to carry out skills training for students with digital and analog knowledge and related knowledge of the microcontroller, consolidate students' comprehensive practical ability, and promote efficient learning with project carrier and result-oriented. Skill competition stimulates students' interest in electronic circuit design, makes students have goals and directions for in-depth learning, and improves their comprehensive design ability and practical innovation ability at the same time.

3.2 Take the results of electronic products as the assessment, establish a learning group, results-oriented to promote students to understand the diagram and improve the diagram

In the course learning, the consistency of circuit schematic and PCB conversion, the component selection of electronic products and the matching degree of PCB packaging, and the circuit welding debugging are the important and difficult points of the course. When students are learning, they often ignore the prototype of the component, and do not pay attention to the consistency of the physical component and the PCB packaging component, resulting in the PCB board that the through hole size design is too small, the position of the component is not enough or the positive and negative direction of the component, and finally make the physical circuit fail.

In the specific teaching, a simple voice-controlled melodic lamp is set up to assess the learning effect of students' basic skills of drawing, PCB design and electronic product production. Let the students try the gap between the drawing design and the physical works, analyze the difference between theory and practice in depth, and establish the practical thinking of the subject engineering. At the end of the semester, the teacher will provide six topics, such as: Dual-circuit DC regulated power supply, production line piece meter, heart color light, cycle color light, single-chip microcomputer learning board, etc. Students choose works suitable for their own difficulty coefficient according to their own ability to make, component learning group, with the help of the learning group, complete the material procurement, schematic drawing, PCB board design and production, welding, debugging and other links. And through the physical debugging feedback to optimize PCB design in order to assess students' engineering practice ability and innovation ability.

3.3 Relying on PCB design innovation and work function innovation practice projects, in order to practice and promote learning, integration of innovation map

Guided by PCB design innovation and work function innovation, students are required to innovate circuits based on given requirements and functions during the course implementation. They need to design PCB boards with small size and low cost while adhering to PCB drawing standards. This approach aims to stimulate students' innovation ability by refining requirements and circuit design standards, clarify engineering practice methods, and strengthen their awareness of innovation. Taking the experimental learning board of the "single-chip microcomputer Application Technology" course as an example, students are guided to design the learning board using modules. This integrates their innovative thinking into comprehensive practice of "single-chip microcomputer learning board" and establishes connections with follow-up courses. Additionally, works demonstrating high levels of innovation will be selected for patent applications and participation in innovation and entrepreneurship competitions. By promoting competition-based innovation, this expands the collaborative development of both in-classroom activities and extracurricular projects while integrating professional skills with innovation and entrepreneurship.

4. Establish the teaching mode of dual innovation practice for both online and offline engineering, and integrate dual innovation in both online and offline settings

4.1 Construction of online boutique open courses

In the era of the Internet, it is crucial to develop a student-centered approach to blended learning that combines online and offline teaching. Our objective is to enhance professional capabilities and foster double innovation abilities through high-quality open courses aligned with the requirements of PCB engineer positions, intelligent hardware, and intelligent electronic product design skills competitions. These courses will incorporate micro-lessons that encompass key knowledge points from typical engineering practices and software operation skills. Furthermore, we will continuously integrate new enterprise cases, industry norms, and processes during the learning process in order to cultivate computer-aided design talents who possess a deep understanding of specifications and fine drawing.

4.2 Build offline and offline mixed teaching and integrate innovation

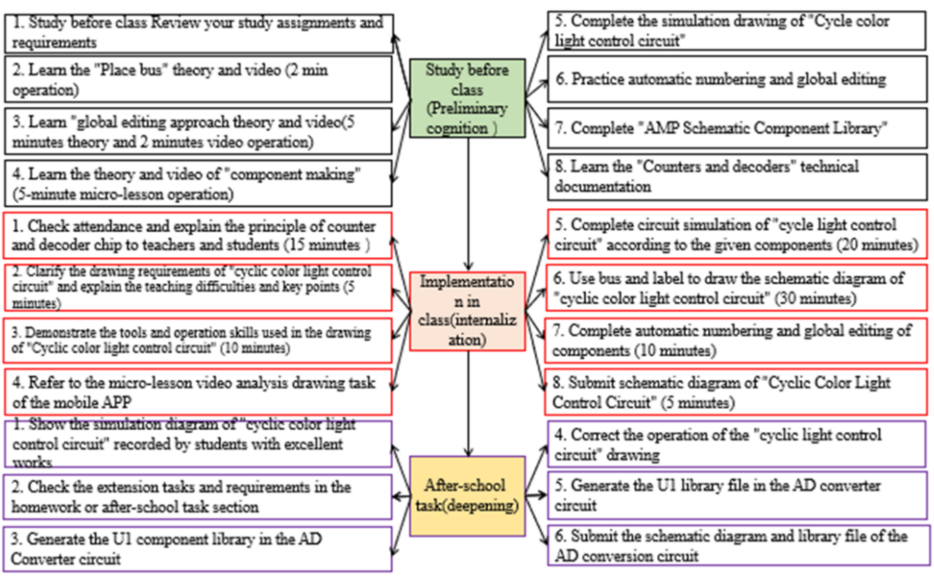

Figure 1. Electronic circuit online and offline hybrid teaching

In this course implementation strategy utilizing the Super Star network course platform (as shown in Figure 1), teachers will integrate EDA software usage techniques into projects based on typical course projects. Prior to class sessions, students can familiarize themselves with upcoming lesson content through micro-lessons while also conducting simulations using software like 'Multisim' or 'Protuse' for preliminary comprehension purposes. During class sessions, the teacher will explain circuit designs and drawing operation, and the students complete the tasks issued by the teacher and master the teaching content according to the requirements of the teacher or the prompts of the micro-class video; After class, the teacher according to the characteristics of typical tasks, sublimation of electronic circuit schematic, set PCB design requirements, the same topic students can discuss schematic design, PCB rule design and component selection costs and other issues after class, strengthen students' teamwork ability and innovation ability, deepen students' professional quality to solve problems.

4.3 Implement the innovation and innovation practice teaching reform of online and offline engineering practice

The implementation effect of the reform practice of the vocational college course 'Electronic Circuit Design' depends on teachers, students, and teaching conditions for cultivating engineering practical innovation ability [5]. In the process of implementation, teachers play a crucial role in promoting practical teaching, which significantly determines the effectiveness of instruction. Therefore, it is encouraged for teachers to engage in relevant enterprises to enhance their proficiency in PCB industry standards and key technologies for PCB design. Teachers frequently engage in communication with technicians within the PCB industry to enrich online course resources, enhance guidance manuals for engineering practice cases, and explore novel innovative scenarios. In the instructional process, variations in students' individual learning abilities impede the attainment of desired learning outcomes outlined in the teaching plan. According to the students' learning and comprehension abilities, project cases with varying levels of difficulty coefficients are designed for students to select from. For instance, students with exceptional learning capabilities can opt for designing an intelligent car core control board, while those with average abilities can choose simpler projects such as cycle lights and other devices. These conventional packaging cases not only bolster each student's professional confidence but also ensure the cultivation of a cohort of outstanding students.

In terms of teaching conditions, challenges arise when placing small orders for PCB production; procuring diverse types and categories of components often results in issues such as incorrect purchases or missed acquisitions. In order to facilitate the implementation of the course, we will establish an electronic product design laboratory and acquire relevant automated PCB manufacturing equipment to address students' concerns regarding PCB fabrication. Moreover, we will compile a procurement list and develop micro-videos elucidating the process and methodologies of component acquisition, with the aim of enhancing students' proficiency in accurately selecting and procuring components. Incorporate the capability to accurately determine appropriate component models for students during the process evaluation.

5 Conclusion

"Electronic Circuit Design" is a vocational course with strong engineering practicality, aiming to cultivate innovative talents with practical engineering abilities. It adopts a job-oriented curriculum structure based on the "three stages and four abilities". Students are assessed through physical works, bridging the gap between theory and practice while strengthening their practical and innovative abilities [6]. Through a comprehensive teaching approach combining online and offline methods, as well as the "three-step" teaching method in the classroom, it achieves a progressive teaching mode of skill acquisition, proficiency, and application. By integrating real electronic product engineering cases' advantages, this course focuses on physically producing electronic products using task-based teaching to enable students to learn while completing tasks. This process facilitates knowledge acquisition, internalization, further internalization while inspiring students to continuously explore the gap between theory and practice in order to enhance their engineering practical abilities. The course also provides a platform for skills competitions that promote learning through competition by encouraging innovation in schematic diagram design, PCB design innovation, and functional innovation in work creation; thus, integrating engineering practice into teaching strengthens students' hands-on ability and significantly enhances their awareness of innovation.

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