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The Construction of Electrical and Electronics Courses under the Concept of Integrating Industry with Education and Converging Science and Education

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Abstract: Electrical Engineering and Electronics, a fundamental course in engineering and technology institutions, faces numerous issues in the traditional teaching model against the backdrop of emerging engineering education and the intelligent transformation of the industry. The teaching team at the University of Shanghai for Science and Technology has benchmarked against the standards of Engineering Education Certification. After 15 years of efforts, they have constructed a multi - dimensional and integrated teaching paradigm of "theory - practice - innovation". Centered around the development goals, in terms of curriculum and teaching reform, the team has strengthened interdisciplinary integration, paid attention to technological frontiers, and promoted the transformation of experiments. In the curriculum content reform, industry applications and cutting - edge technologies have been integrated, and software has been utilized to enhance students' skills. Teaching has been implemented and organized through measures such as building high - level industry - education integration bases, optimizing teaching methods, and integrating ideological and political education. The course adopts an evaluation method that combines process - based assessment and final exams. Remarkable achievements have been made in curriculum construction and students' accomplishments, cultivating students' practical innovation abilities, laying a foundation for subsequent courses and engineering work, and aiming to foster new engineering talents that meet the needs of contemporary society.

1. Introduction

Electrical Engineering and Electronics is a fundamental course in engineering and technology institutions, playing a crucial role in cultivating students' circuit analysis abilities, engineering practical skills, and innovative thinking. In light of the rapid development of emerging engineering education and the intelligent transformation of the industry, problems in the traditional teaching mode, such as an outdated knowledge framework, insufficient practical platforms, and inadequate integration of industry and education, have become increasingly prominent. In response to these challenges, the teaching team of Electrical Engineering and Electronics at the University of Shanghai for Science and Technology has benchmarked against the standards of "Engineering Education Certification." After 15 years of continuous efforts, they have carried out tasks such as the reconstruction of the curriculum system, the development of teaching resources, and the collaborative innovation of industry, academia, and research, and constructed a multi-dimensional and integrated teaching paradigm of "theory-practice-innovation." The construction of the teaching material system for this course began in 2009 and has gone through important stages such as the compilation of national-level teaching materials, the reform of the online-offline blended teaching method, and the collaborative education of industry, academia, and research, forming a demonstration model for curriculum construction. This article systematically reviews the process of curriculum reform, focuses on analyzing the innovative teaching practices under the background of the integration of science and education, aiming to provide useful references for the reform of the Electrical Engineering and Electronics course within the framework of emerging engineering education.

Since the systematic curriculum construction work was launched in 2009, the Electrical and Electronic Teaching Team at the University of Shanghai for Science and Technology has always adhered to the basic concept of "solid foundation, strong practical ability, and promotion of innovation" and established an iterative curriculum development framework. Supporting materials have been gradually introduced, including an exercise collection (2011) [1] and an experimental tutorial (2011) [2], and the teaching material published in 2012 was rated as an excellent teaching material in Shanghai[3]. The publication of the English version of the teaching material in 2016 opened a new stage in the construction of international teaching resources[4]. In 2021, the integration of online and offline resources was successfully achieved. In 2022, through the Ministry of Education's Industry-Education Cooperation and Collaborative Education Project, the school made significant progress in school-enterprise collaborative education. Several education reform papers were published in the same year[5-7]. In 2023, the teaching team officially constructed a structured operation framework, and the achievements of the curriculum group construction were commended. Significant progress was also made in the publication of undergraduate theses in the same year. By 2024, the effectiveness of the curriculum construction was doubly recognized, being rated as a first-class course at the university level and a key curriculum construction project in Shanghai, marking a new stage of high-quality advancement in the development of the course.

With the rapid development of science and technology and the increasing demand for high-quality technical and skilled talents in society, the construction and development of the Electrical Engineering and Electronics course, as an important basic course in engineering institutions, face new challenges and opportunities. Under the background of the integration of industry and education and the integration of science and education, the construction of the Electrical Engineering and Electronics course needs to be closely combined with industry needs. Through measures such as optimizing the curriculum system, updating teaching content, strengthening practical teaching, and innovating teaching methods, students' practical abilities, innovative abilities, and professional qualities should be cultivated[8]. At the same time, curriculum construction also needs to pay attention to in-depth cooperation with enterprises. Through methods such as jointly building laboratories by schools and enterprises, introducing enterprise mentors, and carrying out project-based practical teaching, the organic integration of educational resources and industrial needs can be achieved[9]. In addition, the integration of curriculum ideology and politics provides new ideas for the construction of the Electrical Engineering and Electronics course. By organically combining ideology and politics elements with professional knowledge, the organic unity of knowledge imparting and value guidance can be realized.

2. Research Content

2.1 Objectives of Curriculum Development

The course on Electrical Engineering and Electronics serves as a fundamental component within the electrical and electronic curriculums (as shown in Figure 1) for students pursuing non-electrical disciplines at our institution. In alignment with the school's dedication to addressing the needs of the contemporary engineering sector, the curriculum emphasizes the development of applied, high-level professionals equipped with contemporary engineering competencies. The objectives of the Electrical Engineering and Electronics course are as follows:

1) Learning Objectives: Students are expected to acquire a comprehensive understanding of the fundamental principles of electrical engineering and electronics, encompassing electrical work, analog electronic technology, and digital electronic technology. They should be able to recognize the interrelationships among different concepts and demonstrate proficiency in addressing essential challenges in circuit analysis.

2) Objectives for Skill Development: The primary aim is to enhance students' capacity for self-directed learning and to cultivate an understanding of lifelong learning. This includes the ongoing improvement of students' information literacy, enabling them to independently search for, summarize, and critically assess pertinent literature. Additionally, the program seeks to promote collaborative skills, a global perspective, and innovative practical competencies among students.

3) Quality Objectives: In alignment with the construction goals and the requirements for ideological and political education within higher education curricula, the instructional process prioritizes the development of students' competencies in independently executing tasks such as circuit analysis, electronic circuit design, and debugging. Students are expected to acquire fundamental circuit analysis techniques, with an emphasis on practical application and the conversion of theoretical knowledge into operational skills. The overarching objective is to nurture innovative thinking and problem-solving capabilities, while promoting a work ethic that integrates theoretical

understanding with practical application, is pragmatic in nature, and upholds a scientific and rigorous approach to professional endeavors.

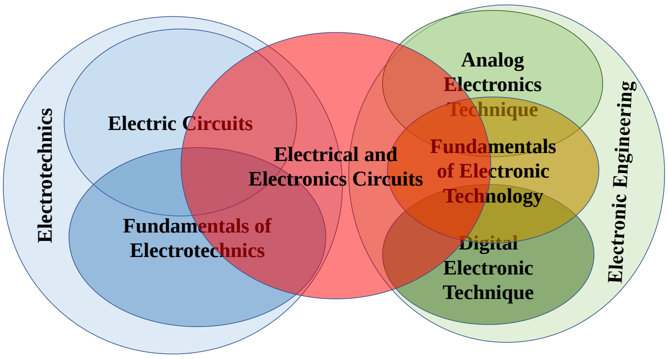

Figure 1 The interconnections among the courses within the electrical and electronic curriculum.

2.2 Principal Considerations for Curriculum and Pedagogical Reform

1) Strengthening interdisciplinary integration and reconstructing the knowledge system: The organic integration of electrical engineering and electronics courses with industry demands presents a significant challenge. It is essential to incorporate industry requirements into the curriculum, adhering to the principle that theoretical knowledge serves practical applications, thereby enhancing the connection between theory and practice. Only through a deep integration of electrical engineering and electronics with industry needs can a distinctive knowledge system be established that meets the demands for cultivating interdisciplinary talent.

2) Focusing on technological frontiers to stimulate innovative spirit: The balance between foundational and cutting-edge theoretical knowledge in the curriculum is crucial. Electrical engineering and electronics serve as a bridge for non-electrical majors to understand electrical courses, providing the necessary foundation for the development of integrated circuits, which represent the forefront of electrical engineering and electronics knowledge. As a foundational course aimed at talent cultivation in the context of new engineering disciplines with a human-centered approach, it is imperative to balance students' foundational knowledge with the characteristics of contemporary technological advancements, thereby enhancing the curriculum's complexity and innovative potential.

3) Implementing a progressive approach to avoid practical shortcomings: The transition between exploratory and confirmatory aspects of experimental content in the curriculum is a critical issue. Utilizing experiments to validate theoretical knowledge acquired in the classroom is an effective method for mastering course content. However, in response to the requirements of contemporary industry-education integration courses, it is necessary to shift from confirmatory experiments to exploratory experiments and practical applications.

2.3 The status of course content, the development of resources, and their application

1) Reform of Course Content

In response to the aforementioned key issues, the reform of the curriculum is primarily focused on three aspects: In response to the aforementioned key issues, the reform of the curriculum is primarily focused on three aspects: The curriculum is structured around the core concepts of electrical engineering and electronics, incorporating foundational theoretical knowledge and technical principles from electrical technology, analog electronics, and digital electronics. Relevant applications and cutting-edge technologies, such as safe electricity usage and electronic device design, are introduced at pertinent junctures, thereby facilitating an organic integration of theoretical knowledge with industrial practice. The curriculum is designed to align with the academic background of undergraduate students, employing a progressive and accessible approach to the foundational theories of electrical engineering and electronics. Additionally, contemporary technologies, such as integrated circuits, are incorporated into the classroom, balancing the foundational and advanced aspects of theoretical knowledge, which in turn stimulates students' innovative thinking.

The curriculum includes the use of simulation software such as Pspice, LTspice, and Multisim in laboratory sessions, along with resource sharing to enhance students' circuit design and simulation skills. Furthermore, the Everycircuit software is provided to assist students in troubleshooting circuit issues, testing new ideas, and exploring new technologies. This approach fosters students' innovative exploration capabilities and increases the challenges of learning, ultimately aiming to cultivate their comprehensive abilities in analysis and problem-solving.

2) Implementation and organization

Leveraging high-level industry-education integration bases, the objective is to develop first-class industry-education integration curricula (as shown in Figure 2 and 3). The establishment of these high-level integration bases involves the construction of practical training facilities and collaborative entrepreneurial incubation centers co-built by schools, government, and enterprises. This initiative aims to create a shared, collaborative educational platform that integrates education, training, and research, thereby enhancing practical engineering experience and fostering students' abilities to address large-scale complex engineering challenges. Currently, there are 18 existing industry-education integration bases. These bases facilitate in-depth discussions on cooperation mechanisms, allowing schools and enterprises to collaboratively develop professional planning and training programs. This approach ensures a deep alignment between the essential competencies required by employers and the core capabilities needed for cultivating new engineering talent. Consequently, a sustainable and effective teaching mechanism is established, promoting a comprehensive understanding of large-scale engineering and ideological education among students, while also serving as a model for nationwide implementation. Each year, industry mentors are invited to deliver lectures at the school, and students are encouraged to engage in practical exchanges within enterprises, thereby co-creating and sharing national-level teaching and research platforms. The successful implementation of industry-education integration not only revitalizes the school's talent cultivation model but also provides robust support for economic and social development. Moving forward, the school will closely align its efforts with industrial and technological advancements, steadfastly advancing educational reforms, and continuously enhancing the quality of education to contribute significantly to regional economic and social development as well as the implementation of the national innovation-driven strategy.

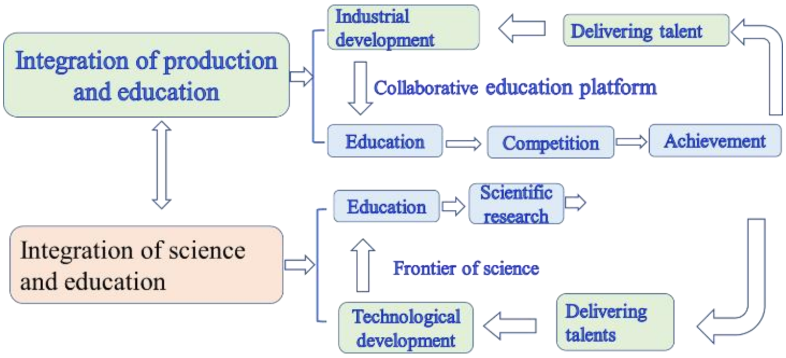

Figure 2 Conceptual Framework for the Integration of Industry and Education in Curriculum Content and Implementation Strategies.

The development of a premier curriculum that integrates industry and education is essential. Grounded in the principle of moral education, it is imperative to continuously advance the reform of the curriculum system. This can be achieved through the enhancement of course content and the innovation of teaching methodologies, thereby improving the quality of industry-education integrated courses. Such improvements aim to bolster students' critical practical skills, innovative thinking, awareness of innovation, and entrepreneurial capabilities, ultimately transforming the Electrical Engineering and Electronics curriculum into a leading example of innovative industry-education integration. To begin with, collaboration between educational institutions and enterprises is crucial for enhancing the quality of curriculum development. Experts from both sectors should align the curriculum with industry demands and the professional development needs of students, incorporating project-based and case-based research-oriented teaching methods into the Electrical Engineering and Electronics curriculum. This approach facilitates a practice-oriented educational design and implementation centered on skill enhancement. The integration of theoretical learning, knowledge application, and skill development should be seamlessly woven throughout the entire curriculum, with a particular emphasis on practical teaching components and the management of the practical teaching process. For instance, the instruction in Electrical Engineering and Electronics can be anchored on an integrated internship and training platform, incorporating real-time, practical scenarios related to safe electricity usage, the testing, assembly, and soldering of electronic components.

Furthermore, it is essential to enhance the quality of the curriculum development team. This can be achieved by fostering collaboration between full-time faculty and industry professionals to create a well-structured curriculum team that combines both full-time and part-time expertise. The curriculum is designed to serve 17 engineering disciplines across the institution, and a teaching team characterized by high political and ideological awareness, as well as substantial teaching experience, has been established.

Furthermore, it is essential to optimize teaching methodologies and integrate elements of ideological and political education into the curriculum. Electrical Engineering and Electronics serve as foundational courses for various engineering disciplines. The pedagogical approach emphasizes the integration of ideological education with knowledge dissemination, merging instructional content with themes such as patriotism, value cultivation, and the development of social responsibility. The specific implementation plan is as follows: the curriculum incorporates the phasor analysis method for active and reactive power in alternating current circuits to elucidate the necessity of energy conservation, thereby fostering students' awareness of energy efficiency. Additionally, the course outlines the historical development and achievements of China's power grid construction, enhancing students' national pride and cultural confidence. Through the demonstration of modern simulation tools, the curriculum encourages students to adopt contemporary engineering practices, thereby cultivating their capacity for lifelong learning. Furthermore, the course discusses the current state and challenges faced by China's electronic component industry, particularly in light of the trade restrictions on high-performance chips imposed by the United States. This discussion aims to inspire a sense of mission among students, instilling a sense of social responsibility and patriotism, while also highlighting the need for perseverance and craftsmanship in the context of China's independent technological research.

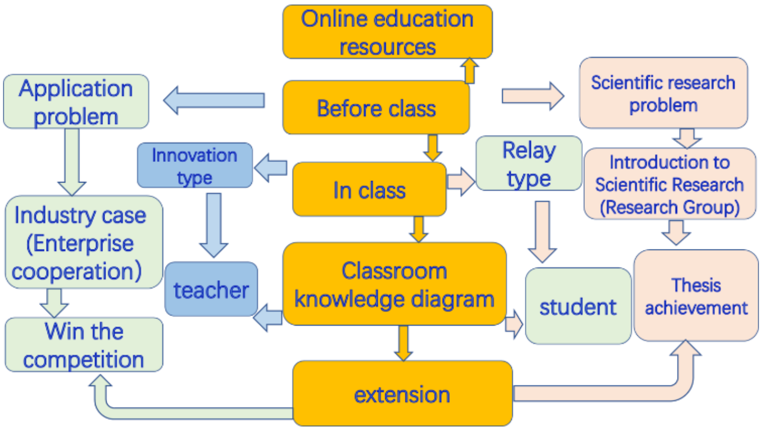

Figure 3 Strategies for the Organization and Implementation of Curriculum Content in the Integration of Industry and Education, as well as the Convergence of Science and Education.

In terms of course resource development, the primary forms of instructional materials include a syllabus guided by ideological education principles; presentation slides rich in ideological case studies; recorded online course resources infused with ideological elements; short video materials that encapsulate relevant ideological content; and the establishment of a simulation engineering library that aligns with engineering practice.

2.4 Overview of Course Content and Implementation Strategies

1) Method of Assessment for Course Grades

To enhance students' practical innovation capabilities, it is essential to reform the assessment and evaluation methods employed in academic settings. This includes providing undergraduate students with access to on-campus innovation and practice platforms, as well as increasing the availability of specialized laboratories to facilitate the sharing of educational and research resources. The evaluation of coursework should emphasize a process-oriented approach, focusing on students' abilities to apply course knowledge in analyzing and resolving practical issues. Assessment criteria should align with engineering accreditation standards, incorporating continuous assessment of students' performance. This may involve the introduction of non-standardized examination formats, as well as diverse assessment methods such as comprehensive assignments, presentations, and research papers to evaluate students' knowledge and competencies.

The course assessment framework will consist of two components: process-oriented assessment (50%) and a final examination (50%). The process-oriented assessment will be divided into five categories: 1) Assignments (10%), which will reflect students' regular homework performance; 2) Expansion (10%), which will assess students' submitted case studies related to course applications; 3) Design (10%), which will evaluate students' practical or simulation project designs; 4) Classroom Participation (10%), which will measure students' performance in classroom discussions; and 5) Midterm Examination (10%).

2) Assessment of Course Effectiveness and Reform Initiatives

The preliminary completion of the curriculum development has been achieved, focusing on a "competency-based" framework, the establishment of "open and multi-source" teaching resources, the exploration of a "student participatory" instructional model, and the optimization of curriculum development through a "continuous feedback loop." Centered on the theme of promoting high-quality development, this initiative adheres to a pedagogical approach that integrates academic and industry collaboration, thereby enhancing the educational outcomes of the Electrical Engineering and Electronics course. In recent years, the achievements of this curriculum development have been significant and have received recognition from various stakeholders.

3) Course Development Achievements

In 2024, the course "Electrical Engineering and Electronics" was approved as a key project for the integration of industry and education in Shanghai. Additionally, it was recognized as a first-class course construction project at the University of Shanghai for Science and Technology in the same year. In 2023, this course received the First Prize for Excellent Teaching at the University of Shanghai for Science and Technology, as well as the Third Prize for the construction of the Electrical Engineering and Electronics course group. In 2022, it was approved as a collaborative education project by the Ministry of Education, titled "Innovative Practice Platform for Collaborative Education in Automation." Furthermore, three research and teaching reform papers were published in 2022.

4) Educational Impact of the Course

The course emphasizes ideological education, effectively exploring the educational elements inherent in "Electrical Engineering and Electronics." It utilizes the integration of industry and education as a platform to enhance the development of students' competencies and qualities. Scientific and Technological Innovation Outcomes: By integrating theoretical knowledge from "Electrical Engineering and Electronics" with practical design cases of electronic components from industry, students were guided to design ultra-high sensitivity sensors based on micro-nano super surfaces. Several students, as first authors, published multiple research papers in SCI journals. Additionally, undergraduate students received the National Excellent Award in the Blue Bridge Cup National Software and Information Technology Talent Competition, as well as multiple first and second prizes at the provincial and ministerial levels, including the First Prize in the "Desifuge Cup" Shanghai

Creative Robot Challenge. Students were also guided in initiating several university innovation and entrepreneurship projects, which received "Excellent" ratings during their final defense and were recognized at the national level.

3. Conclusion

This course proposes a teaching model that emphasizes the integration of industrial case studies and cutting-edge research within the framework of industry-education integration, supported by the Ministry of Education's collaborative education practice project. This approach not only enhances students' comprehension of classroom knowledge but also cultivates their practical skills and research innovation capabilities. The course employs a blended teaching approach in accordance with high-quality course standards. By adhering to the FD-OM standards, the course design is refined across core indicators such as learning objectives, academic assessment, course activities, and learning support. This comprehensive enhancement aims to achieve a goal-driven, standardized, measurable, and feedback-oriented task-based blended teaching model. The design of the online and offline educational components incorporates digital resources, utilizing self-developed virtual simulation experiments to facilitate autonomous learning both inside and outside the classroom. A highly customized online classroom platform is employed to gather effective data feedback on various aspects, including student engagement, learning investment, learning preferences, content coverage, learning pace, learning speed, and learning modes. This data serves as a robust foundation for personalized instruction. The teaching methodology that integrates science and education within this blended industry-education framework not only establishes a theoretical and practical foundation for subsequent courses and engineering-related work but also enhances students' problem-solving abilities, practical skills, scientific research capabilities, and innovative exploration skills. This approach aims to cultivate new engineering talent that meets the demands of contemporary society.

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