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Research on the Teaching Reform of Experimental Courses for Electrical Engineering Majors under the Background of "Emerging Engineering Education"

-- Taking "Power Electronics Technology" as an Example

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Abstract

In the context of the construction of "Emerging Engineering Education", the development of the electrical engineering specialty and the cultivation of talents in related fields present new requirements. The teaching reform of the experimental course of power electronics technology is being carried out in three aspects: firstly, the goal of the reform is being clarified; secondly, the implementation plan is being formulated; and thirdly, the effectiveness of the reform is being evaluated. The overarching objective of this initiative is to establish a framework that will facilitate the nurturing of applied talents within the electrical engineering discipline.

Keywords

Emerging Engineering Education; Electrical Engineering; Teaching Reform of Experimental Courses; Power Electronics.

1. Introduction

Emerging Engineering Education (3E) represents a reform of engineering education in the context of industrial change and technological revolution in the new era, constituting an innovative approach and exploratory practice for the connotative development of engineering education in China. The construction of 3E entails not only the implementation of the new requirements of moral education, but also the comprehensive implementation of "innovation-driven development" and "Made in China 2025" and other national strategic development, and the construction of cutting-edge technology international competition in the new needs[1].As a traditional engineering specialty, electrical engineering is one of the core and key disciplines in the field of modern high-tech, and its professional development and talent cultivation in related fields have attracted much attention under the background of Emerging Engineering Education.

The experimental course of electrical engineering plays a pivotal role in facilitating the integration of theoretical knowledge with practical technical skills. The teaching reform of this course, grounded in the principles of the 3E model, holds immense potential in enhancing students' practical innovation abilities. However, past teaching practice has been found to be encumbered by a retrograde teaching concept [2], an inadequate teaching content [3], and a paucity of application [4], among other issues. The present paper, drawing on the author's experience of teaching a power electronics technology experimental course, aims to reform the experimental course in electrical engineering. This will be achieved by clarifying the reform goal, formulating an implementation plan and evaluating the effectiveness. The paper will provide a reference point for the training of electrical engineering professionals.

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2. Current Situation of Experimental Teaching

2.1. Teaching philosophy needs to be updated

The advent of "Emerging Engineering Education" has precipitated a paradigm shift in the realm of traditional engineering education, heralding an era of heightened expectations and challenges. This paradigm shift entails a re-evaluation of the conventional teaching methodologies and the cultivation of talents. The integration of the concept of 'new engineering' into the pedagogical process is imperative to align with the training requirements of practical and innovative talents in the domain of electrical engineering. In many leading universities around the world, engineering education certification serves as the standard for conducting experimental course teaching, thereby establishing elevated expectations for experimental course instructors. This certification emphasises cultivating students' competencies in problem-solving within complex engineering scenarios, necessitating interdisciplinary thinking and robust practical skills. Power electronics technology, a prominent field in electrical engineering, is characterised by its intricate nature and the necessity for advanced problem-solving capabilities. Consequently, it is imperative for educators to maintain currency in their pedagogical approaches, aligning their instructional concepts with the evolving demands of the industry to ensure relevance and effectiveness in the context of "Emerging Engineering Education" construction.

2.2. Laboratory construction needs to be improved

At present, the majority of the experimental content of power electronics technology in higher education institutions is focused on functional auxiliary verification of course teaching, with a limited number of experimental contents and reduced class hours.In terms of laboratory facilities and equipment, from the perspective of students' hands-on operation, this kind of experimental equipment is aesthetically pleasing and convenient to operate. Following a teacher's explanation and demonstration, students can complete the experimental operation with ease. However, from the perspective of students' open and innovative thinking, the internal electrical components of each module of this kind of experimental device have been completely connected and sealed in the experimental box. The experiment can be completed by students through a basic circuit connection, yet they are unable to comprehend the internal circuit structure of each module, which significantly restricts their capacity for innovative thinking and hinders the manifestation of their subjective initiative in learning [5].

2.3. Disconnect between talent training and industry

In the context of rapid industry development, there is an imperative to overcome technical challenges and enhance production efficiency. This can be achieved by placing significant reliance on technological innovation. Consequently, the electrical industry is characterised by a perpetual cycle of innovation, with numerous novel technologies and equipment being utilised in industrial applications. However, in the context of experimental teaching of power electronic technology in higher education institutions, the conventional verification experiment persists. While these experiments may offer insight into fundamental principles, such as single-phase half-wave and full-wave rectifier circuits, they often lack practical relevance in terms of cultivating students' core competencies. Moreover, these experiments are often not aligned with the complex circuit scenarios prevalent in contemporary industrial practices, resulting in a discrepancy between educational objectives and industry demands.

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3. The Objectives of Teaching Reform

3.1. Improving laboratory construction

In the context of higher education, the experimental component of power electronics technology is predominantly focused on the verification of fundamental auxiliary functions. The curriculum is predominantly limited to a single experimental element, and the allocated time is relatively modest. In terms of laboratory facilities and equipment, from the point of view of the students' hands-on level, this kind of experimental equipment is aesthetically pleasing, straightforward to operate, and students can easily complete the experimental operation through the teacher's explanation and demonstration. However, from the point of view of the students' open innovation level of thinking The experimental device under scrutiny in this study has been designed to facilitate a complete connection of the internal electrical components of the module, with the experimental box acting as a sealant. The students are required to establish a connection to a simple line in order to complete the experiment, with no requirement for them to intuitively understand the internal circuit structure of each experimental module. This has the effect of significantly restricting the students' ability to innovate. The absence of intuitive comprehension of the internal circuit structure of each experimental module significantly restricts students' innovative development, hindering the full expression of their subjective initiative[5].Consequently, the teaching reform of power electronics experimental courses, encompassing the iterative introduction of school experimental equipment and digital experimental resources, has been proven to enhance the teaching efficacy of experimental courses. Concurrently, efforts are underway to enhance the laboratory facilities, implement a refined laboratory management system, and establish a secure and pragmatic experimental environment for students, thereby ensuring the seamless integration of power electronics technology in experimental teaching.

3.2. Innovating experimental courses teaching mode

In 2023, the Ministry of Education of the People's Republic of China, in conjunction with seven other ministries and commissions, promulgated Several Opinions on Further Strengthening Practical Parenting in Colleges and Universities. These opinions explicitly articulate the pivotal role and significance of practical parenting within higher education institutions. The aforementioned institutions are charged with the promotion of professions through the enhancement of innovation and reform in practical teaching methodologies and approaches. The experimental teaching mode, as a pivotal conduit for cultivating engineering students, serves as an extension and refinement of theoretical teaching, thereby fostering students' engineering consciousness, practical skills and innovation capabilities. In the contemporary era, the realm of engineering technology is undergoing rapid advancements. Consequently, the conventional experimental teaching methods, which rely on observational learning and rudimentary operational procedures, are no longer adequate to meet the industry's demands for students' practical capabilities and innovation skills. In addressing these challenges, we have undertaken a comprehensive curriculum review and innovation in experimental teaching methodologies. This has entailed the enrichment of experimental course content and the adaptation of teaching methods to align with industry advancements. The incorporation of digital technology has been instrumental in enhancing the complexity and comprehensiveness of experiments, thereby enriching the student experience. Furthermore, by actively seeking external program support, students can gain industry insights through a dual approach of on-campus experimentation and off-campus practical experience.

3.3. Enhancing the quality of teaching in laboratory courses

Professional accreditation of engineering education constitutes an internationally recognised quality assurance system for engineering education. In China, it represents a pivotal component

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of the teaching assessment of engineering majors, aligning with the three fundamental concepts of student-centredness, result-orientation and sustainability. This accreditation system serves as a crucial criterion for enhancing the talent cultivation objectives of engineering education[6]. Power electronics technology is a foundational course in electrical engineering, necessitating a high level of practical innovation from students. Consequently, the experimental class serves as a crucial extension of theoretical teaching, facilitating the operationalisation and visualisation of complex theoretical knowledge. Through experimental operation, students can develop a more intuitive understanding of how the fundamental knowledge points of the course are realised in practical operation and industry application. In light of the "new engineering" paradigm and the objective of engineering education certification, we have adopted a series of measures to enhance the practical proficiency and innovative thinking of students. These measures encompass the following: a focus on outcome-oriented thinking, continual enhancement of laboratory infrastructure, optimisation of experimental content, innovation in experimental teaching methodologies, and reformulation of experimental course assessment. These measures are designed to not only bolster students' ability to apply subject knowledge in complex scenarios but also to equip them with the necessary skills to tackle sophisticated engineering problems in the domain of power electronics technology. This, in turn, provides a robust foundation for cultivating applied talents in the field of electrical engineering.

4. The Implementation Program for Teaching Reform

4.1. Upgrading of laboratory equipment

The school's power electronics technology laboratory utilises the DJDK-1 type power electronics technology and motor control experimental device, which employs a pendant structure. This experimental apparatus boasts a versatile design, allowing for straightforward integration into diverse experimental content. Its functionality and comprehensive nature facilitate its use in a range of settings, including those associated with power electronics, automated control systems, and motor control. The experimental device is a valuable addition to the curriculum, offering a comprehensive solution for traditional experimental projects. The utilisation of the aforementioned experimental device is conducive to the fulfilment of the experimental requirements intrinsic to the traditional power electronics technology course. However, from the perspective of "Emerging Engineering Education" and engineering education certification, electrical engineering personnel must possess the capacity to undertake the practical application of complex engineering problems. Relying exclusively on conventional testing experiments is inadequate in this regard. Consequently, in accordance with industry requirements, the hardware, software, facilities and management systems of power electronics laboratories in educational institutions must be continuously updated and enhanced. For instance, in the context of the "double carbon" initiative, intelligent microgrids have become a prevalent component in the development of novel power systems, primarily reliant on renewable energy sources such as wind power and photovoltaic power generation. The integration of a microgrid experimental platform within the laboratory milieu facilitates students' profound comprehension of the practical implementation of power electronics technology at the vanguard of the industry, thereby enhancing the efficacy of their training in practical innovation abilities.

4.2. Strengthening teacher training

The competence of laboratory teachers has been demonstrated to have a significant impact on the quality of students' innovation ability training. It is recommended that the combination of practice and theory be considered in the selection and training of teachers. Firstly, in the selection and recruitment of laboratory teachers, it is essential to thoroughly examine their professional background and pre-service learning and training, rather than relying solely on

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academic achievements or theses. It is crucial to consider their experimental ability, if applicable, to avoid a rigid pattern that might hinder the identification of talent. Those who demonstrate exceptional ability should be selected and recruited to pursue higher levels of study or to accumulate front-line practitioner experience. Secondly, there is a need to strengthen the training of in-service laboratory teachers. It is recommended that experimental course teachers participate in workshops, on-the-job enterprises and other forms of integration into the industry, with industry practice cases being brought back to the campus. Thirdly, experimental teachers should be encouraged to obtain other technical job series titles through the evaluation process, as far as possible, in addition to the required evaluation of experimental series titles. The creation of a dual-teacher experimental teacher team should be facilitated. Fourthly, the evaluation and assessment of laboratory teachers should be strengthened. This should be achieved through a combination of student evaluation, teacher evaluation, skills assessment and other qualitative methods to increase the "assessment for teaching" assessment, to promote teaching and learning.

4.3. Optimizing the content of teaching

In the past, the course of power electronics technology was arranged for 16 hours, including 1 electronic instrument test experiment and 7 circuit experiments, mostly based on simple verification and basic experiments. However, for the experimental class, its most important essence is the epitome of engineering problems. Therefore, in the optimization of the teaching content of the electric power technology experiment course, the solution of complex engineering problems should be considered, and the cross-integration of multiple disciplines should be emphasized as much as possible on the basis of traditional experiments. The experimental content can be divided into three experimental sections : verification, design and comprehensiveness. Through the setting of different experimental types, students can not only master the knowledge base they should have, but also exercise their ability to comprehensively use curriculum knowledge to solve complex engineering problems. For example, the traditional single-phase half-wave controlled rectifier circuit, three-bridge half-controlled rectifier circuit and other experiments can be used as verification experiments for students to master the basic principles of rectifier circuits ; the experimental projects such as the performance research of DC chopper circuit and single-phase frequency conversion circuit can be used as design experiments for students to operate. If the experimental conditions permit, comprehensive experiments such as three-phase PWM rectifier experiments can be carried out to improve students ' engineering practice literacy. Furthermore, virtual simulation can be incorporated into experimental teaching content. By simulating the laboratory environment, circuit construction and other interactive links, students are able to operate in the virtual space, thus facilitating a more profound comprehension of the working principle and design process of power electronics.

4.4. Enrichment of teaching sessions

The passive input of knowledge in the theoretical courses will make students lack the sense of independent learning and self-reflection. Therefore, in the process of experimental teaching, based on the principle of professional accreditation of engineering education, the main body of the course should be changed from the teacher to the students, and through the establishment of learning groups and the development of flipped classroom teaching activities and other means, the enthusiasm of the students in the experimental course should be mobilised, so that the students can change from the passive reception of knowledge to the independent exploration of knowledge. Before the class, students are allowed to freely form study groups, and at the same time, the boutique online classes, operation videos and hot industry information involved in the experimental course are packaged and provided to students for theoretical knowledge review, group discussion and division of labour. During the class, it is

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divided into three parts: teacher-student interaction, experimental operation and group discussion report. The teacher-student interaction part consists of the teacher and students reviewing the corresponding theoretical knowledge of the experimental course, the students drawing circuit diagrams and explaining the experimental equipment wiring steps, and the teacher commenting; the experimental operation part consists of the student group completing the experimental wiring, waveform demonstration and data recording according to the division of labour within the group. In addition to composing the experimental report, students are encouraged to engage actively in the Challenge Cup, the National College Students Electronic Design Competition, the Internet + Contest and other competitions. These competitions are designed to stimulate students' independent learning and enhance the effectiveness of experimental teaching methods. Furthermore, it is imperative to arrange for teachers to lead students on in-depth visits to school enterprise practice bases on a regular basis. This will enable students to formulate intuitive feedback on the practical application of power electronics technology and establish a closed loop of learning.

4.5. Innovative teaching methods

In accordance with the principles of engineering education certification, the experimental teaching process is to be student-centred. In order to achieve this, it is necessary to correctly grasp the relationship between teaching and learning, make good use of a variety of teaching methods, and strengthen students' independent innovation from different angles, with a view to improving their practical and innovative ability.In addition to the traditional classroom teaching method, the following teaching methods can be used: one is the task-driven method. At the commencement of the experimental class, the subject matter is articulated through multimedia courseware, and the experimental tasks are arranged.In addition to completing the fundamental wiring tasks, students are guided to actively expand the tasks, such as completing the task of 'single bridge controllable rectifier circuit provides adjustable DC power for DC motor' in the rectifier circuit part.The second method is the flipped classroom method. The learning group is required to divide and cooperate for the expansion task, and record the experimental process and data.In the second class, the group demonstration and group report are carried out to improve the students' participation in the teaching process. The third is the project teaching method. The students are permitted to participate in professional-related practical competitions and teachers' vertical and horizontal scientific research projects, and thereby become involved in the complete implementation process of a project. This allows them to clarify the application of professional knowledge in different project cycles from the whole chain of project planning, design, implementation, transformation and evaluation. The experimental content is specific and project-oriented, and thus the students' learning career and practical ability are expanded.

5. Evaluation of the Effectiveness of Teaching Reform

The efficacy of teaching reform must be subject to rigorous evaluation. Firstly, it is necessary to carry out the evaluation of students' learning outcomes. In the context of experimental courses, it is imperative to employ a multifaceted evaluation framework that encompasses both experimental reports and a range of other metrics. This ensures that students receive a scientific, equitable, and unbiased assessment. The assessment standards are set up from pre-class, in-class and after-class, according to the setting of teaching links and teaching contents. Prior to class, students' theoretical course learning situations and their preliminary engagement with the pre-class learning package are evaluated through various platforms, including the learning management system and other digital tools. Within the course, the fundamental experiment is used to assess students' theoretical learning. In the case of design experiments, the students' rationality, safety and successful completion of the experimental

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content design are examined. In the context of the comprehensive experiment, the students' integrity of experimental design and operation is examined, and the experimental content and difficulty are scored respectively. Group collaboration is also a significant component of the class assessment. Following the conclusion of the experiment, the students' learning outcomes and summarising abilities are evaluated through the experimental report and the practical report.

Secondly, it is necessary to carry out the evaluation of teachers' curriculum design, and to evaluate the curriculum design itself through student evaluation, teacher self-evaluation, peer evaluation, expert evaluation and other methods. Through the utilisation of questionnaires, student interviews, and other methodologies, students can evaluate the laboratory construction, the pedagogical proficiency of the faculty, the experimental design, and other pertinent aspects. This, in turn, serves to promote teaching and learning. Teachers must regularly and irregularly review and reflect on the rationality, completeness and practicability of the content of the teaching design, review the details of the teaching process, and adjust the teaching methods and strategies. Concurrently, the involvement of theoretical and peer experimental teachers in regular class attendance, evaluation of teaching processes from diverse perspectives, and promotion of teaching quality enhancement, is paramount. In addition, the implementation of expert evaluation is imperative, with the invitation of specialists in theoretical and experimental domains, as well as those with extensive industrial experience, to undertake a comprehensive evaluation of the content of teaching reform. The focal point of this evaluation should be on the efficacy of the content of teaching reform in establishing a connection with industrial practical application.

In conclusion, it is imperative to ensure the efficacy of the subsequent investigation of graduate students. The establishment of a contact mechanism for graduate students at the college level is imperative, as is the active maintenance of contact with graduate students through platforms and channels such as alumni associations and course groups. Furthermore, it is crucial to ascertain the actual feedback of students employed in related industries. Concurrently, it is imperative to enhance communication with relevant industrial enterprises and graduate work units, and to conduct seminars and research meetings on site in a timely manner to ascertain the specific requirements of enterprise technical posts for students' practical ability and the ability of graduates in the post. The findings from this research, combined with insights from industry feedback, will inform the refinement and deepening of teaching reforms.

6. Conclusion

In the context of the "Emerging Engineering Education" construction initiative, the reform of power electronics technology experiment teaching emerges as a pivotal strategy for enhancing students' practical innovation capabilities within higher education institutions. The teaching reform strategy entails a clear delineation of the teaching concept, emphasising that the ability to resolve complex engineering problems is identified as the paramount indicator of students' practical innovation competence. The experimental equipment is being upgraded and experimental teachers are being trained in order to address the problems existing in the experimental teaching of power electronics technology. Concurrently, the teaching links are being adjusted, the teaching contents are being enriched, the teaching methods are being updated, and the teaching reform is being carried out in a multi-dimensional and three-dimensional way. The goal to be achieved is the improvement of laboratory construction, the updating of the experimental teaching mode and the improvement of the quality of experimental teaching. It is imperative to evaluate the efficacy of these reforms by assessing students' learning outcomes, teachers' teaching methods, and graduates' post-competency achievements, thereby ensuring the success of the teaching reform initiative.

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