Journal of Education and Educational Research
ISSN: 2957-9465 | Vol. 17, No. 3, 2026

Research on Experimental Teaching of Computer Network Courses Based on Engineering Education Concept

Linlin Li, Liangxu Sun *, Guangwu Ao

College of Computer and Software Engineering, University of Science and Technology Liaoning, Anshan Liaoning, 114051, China
*** Corresponding author:** Liangxu Sun

Abstract: Under the traditional teaching concept, the experimental teaching of computer network course has the problems of emphasizing teaching over learning, low level of learning outcome and lack of continuous improvement mechanism. Introduce the student-centered, outcome-oriented education and continuous quality improvement concept of engineering education professional certification to carry out experimental teaching reform. According to the graduation requirements supported by the course, a number of course objectives are designed, the organization process of multi-type and multi-level experimental teaching is improved, the evaluation standards of final, formative and multi-level course objectives are established, the virtual and real combination experimental environment and campus network engineering project example in the teaching implementation process are described, and the course objective evaluation results of all students in a complete teaching round are provided, which proves that the experimental teaching reform of computer network course under the concept of professional certification of engineering education is feasible and effective.

Keywords: Engineering Education; Computer Networking; Experimental Teaching; Student-Centered; Outcome-Oriented Education; Continuous Quality Improvement.

1. Introduction

In June 2013, China joined the Washington Agreement and launched the international equivalent professional certification of engineering education [1-2]. The professional accreditation of engineering education follows the concepts of Students-Centered (SC), Outcome-Based Education (OBE), and Continuous Quality Improvement (CQI) [3-4]. Student-centered emphasis is placed on resource allocation and teaching arrangement for all students to achieve training goals, graduation requirements, and curriculum goals. The students' evaluation results are used as an important basis for professional evaluation [5-6]. Output-oriented education emphasizes that instructional design and implementation are guided by students' learning outcomes in the learning process, and teaching evaluation is carried out according to professional ability goals and evaluation standards[7-9]. Continuous quality improvement emphasizes the ability to continuously monitor teaching quality, and to continuously improve teaching according to the results of teaching quality evaluation, and establish effective quality monitoring and continuous improvement mechanisms[10-12]. These concepts are crucial to guide and promote professional construction and teaching reform, and to ensure and improve the quality of engineering education talent training.

Computer network courses are very important professional basic courses for computer-related majors. Students can master the knowledge system and working principles of computer networks, be familiar with the mainstream technology of computer networks, establish computer network thinking, and have the ability to analyze network problems and practice network technology. The theoretical teaching takes the hierarchical model of computer network architecture as the main line, introduces the basic principles of computer networks, introduces the functions, protocols and working principles of the physical layer and data link layer in combination with LAN and WAN networks, and introduces the functions, protocols and working principles of network layer, transport layer and application layer combined with TCP/IP protocol clusters. Experimental teaching for IP network networking, LAN management, TCP/IP application service deployment, etc.

It is of great significance to introduce the concept of engineering education professional certification into the experimental teaching of traditional computer network courses, and to discuss how to solve the current problems of emphasizing teaching over learning, low level of learning outcomes and lack of continuous improvement mechanism.

2. Experimental Teaching Problems

2.1. Emphasize Teaching Over Learning

Teaching refers to what, how and how to teach. And learning refers to what, how and how to learn. Teaching under the traditional teaching concept attaches importance to the teacher's teaching and despises the learning of students.

In experimental teaching, teachers generally pay attention to the content required by the syllabus and teaching plan, and complete the teaching task when the content is completed. Teachers issue experimental content before experiments, requiring students to complete the experiment by themselves according to the class schedule, generally do not pay attention to the students' experimental process, and complete the teaching task after the students complete the experiment and submit the report. Teachers generally only evaluate grades based on students' reports, and the evaluation lacks objective and reasonable standards, and is more of a subjective judgment on the overall content of the report.

From the perspective of teaching essence, concept and principle, teaching under the traditional teaching concept is the process of teachers imparting knowledge and skills to students, for the purpose of teaching, teaching to evaluate teaching, and teachers to evaluate how to teach. The teaching under the concept of engineering education professional certification is to teach students how to learn, and students must be able to learn, learn and think by themselves, for the purpose of learning. Teaching should take students as the main body, with students enjoying learning, learning and learning as the purpose, and evaluate teaching by learning.

2.2. The Level of Learning Outcomes is Low

Under the traditional teaching concept, the classroom mostly adopts the cramming knowledge indoctrination method, the teacher provides authoritative knowledge, the students accept the knowledge unconditionally, and the teaching process becomes a simple knowledge replication process.

In experimental teaching, teachers generally only determine the experimental content according to the knowledge organization structure of the textbook, only pay attention to the learning results of students' knowledge, emphasize the complete coverage of knowledge, and ignore the higher ability and quality learning results. The design of experimental content is not for the purpose of ability training and quality improvement. The experimental process lacks interactive communication, questioning and solving doubts, emotional and psychological experience, ideological and political education, etc.

The concept of professional certification of engineering education requires the construction of professional knowledge, ability and quality structure, and forms the basic basis for carrying out teaching activities. The learning outcomes achieved by students include three levels: knowledge, ability and quality. It is necessary to transform one-way indoctrination into multi-way communication, so that knowledge can be transmitted, exchanged and interacted between teachers and students and students. Teachers should guide students to ask questions about knowledge, not just talk about it, solve problems through thinking and practice, and acquire the ability to apply knowledge. Further, it is also necessary to enable students to feel the beauty of knowledge emotionally, understand the power of knowledge ideologically, stimulate enthusiasm and interest in learning, establish correct values, and improve personal quality.

2.3. Lack of Continuous Improvement Mechanism

The core of the improvement mechanism lies in evaluation, without evaluation, we do not know what to change, there is no basis for improvement, there is no analysis and research of evaluation results, and the change may not be effective.

The evaluation under the traditional teaching concept is more of a simple accumulation or average of learning outcomes, which is used to evaluate students' mastery of knowledge, and is rarely used to evaluate ability and quality performance. Teaching quality evaluation only focuses on form and is not directly related to the achievement of curriculum goals. There is a lack of output-oriented curriculum goal setting and evaluation, the specific output is unclear, effective evidence cannot be provided, the ability and quality evaluation is unreasonable, and the evaluation standards are vague.

In experimental teaching, the evaluation index points are immeasurable, and most of them are based on the subjective evaluation of teachers. The experimental results were weighted and averaged, but the weighted part did not reflect the ability evaluation. Students use mutual evaluation, and points are given for participation, and the experimental content does not correspond to the ability indicators, which is too simplistic. The evaluation method lacks rationality judgment, and the evaluation results are meaningless. The evaluation is completely decided by the teacher, who evaluates himself and does not review it. According to the learning results, such as experimental reports, the score is calculated directly, and the rationality of the connotation of the score is not paid attention to at all.

Under the concept of engineering education professional certification, evaluation is the core, mechanism is the guarantee, and improvement is the goal. Learning results are not disregarded as results in the learning process, but should be evaluated in stages. Find and analyze students' ability shortcomings through the achievement of curriculum goals for continuous curriculum improvement. Only when the concept is correct, the mechanism is formed, and the measures are in place can we continue to improve.

3. Experimental Teaching Design

3.1. Curriculum Objective Design

According to the "General Standards for Engineering Education Accreditation" of the China Engineering Education Accreditation Association, the professional training objectives and graduation requirements are revised, the graduation requirements are decomposed according to the index points, and the graduation requirements are determined to evaluate the courses. Design the course objectives according to the graduation requirements supported by the computer network course.

Educator Bloom divides the cognitive process into six levels: memory, understanding, application, analysis, evaluation, and creation, with the first three being at the lower level and the last three being at the higher level. Low-level teaching activities require low-level declarative knowledge and cultivate low-level abilities. High-level teaching activities require high-level procedural and strategic knowledge, and cultivate high-level abilities. Therefore, the experiment is divided into different levels of validation, design and comprehensiveness, and the curriculum objectives of different levels are designed to cultivate students' abilities at different levels.

The purpose of experimental teaching is to be able to perform topology design, device configuration and data analysis in virtual and physical network environments, to be able to display, verify and analyze the abstract working principle and data encapsulation of the protocol, to be able to obtain effective conclusions according to protocol theory, and to have the ability to analyze and design common and important protocols. The curriculum objectives are designed as followed:

Course objective 1: Be able to use common analysis charts in computer disciplines, normative languages of network engineering, and network protocol analysis tools used in physical and virtual networks for the expression of network architecture, network protocol working principles, and network equipment working processes.

Course objective 2: Be able to use network simulator tools to establish network topology in a virtual network environment, complete device selection, link connection, address planning and protocol configuration for network equipment, network links, network addresses and network protocol specific objects in the network topology involved in complex network engineering problems.

Course objective 3: Be able to use the knowledge of network protocol principles, TCP/IP and OSI/RM models, and network protocol analysis methods to deduce and analyze network communication involved in complex network engineering problems.

Course objective 4: Be able to use the basic principles of network protocols, with the help of RFC documents and network information resource literature research, analyze the influencing factors of equipment selection, link connection, address planning and protocol configuration in the process of network communication problems, and obtain effective conclusions about the causes of communication problems.

Course objective 5: Be able to select and use GNS3 virtual machine, Packet Tracer simulator, Wireshark network protocol analysis tool, RFC documents and network information resources to perform network communication analysis, address planning calculation, and network topology design for complex network engineering problems.

3.2. Experimental Teaching Design

3.2.1. Multi-Type Experimental Design

The main content of the validation experiment is to verify the principles of the protocol, including syntax, semantics, and synchronization rules, which are explained by standard RFC documents, which will not change with business requirements, and are suitable for verification by protocol analysis tools in physical or virtual network environments. The main purpose of the validation experiment is to enable students to use tools to build a network environment, capture protocol packets, express the protocol working process, and verify the protocol principle.

The main content of the design experiment is to first specify a LAN or WAN business scenario, such as Ethernet communication and dynamic address allocation in the campus network, multi-segment routing communication in the enterprise network, and NAT communication on the internal and external networks. Then analyze the requirements, design the network topology and device functions, plan IP addresses, device selection and link connections. Finally, the network requirements are realized, equipment configuration, functional testing, troubleshooting and writing schemes are carried out. The main purpose of design experiments is to enable students to design independent and simple solutions according to the needs of specific business scenarios, complete the analysis, design and implementation processes similar to real system solutions, and cultivate the ability to establish design ideas, apply design methods, deploy network equipment, accumulate troubleshooting experience, and write technical documents.

The main content of the comprehensive experiment is to specify a complete business scenario similar to a real network system and target a variety of application services. Different from design experiments, this business scenario should comprehensively use multiple technologies to solve multiple requirements. It mainly includes equipment selection and link connection communication problems at the physical and link layers of the physical network in LAN or WAN, dynamic and static allocation of IP addresses in IP logical networks, IP address conversion problems in internal and external networks, dynamic and static routing selection problems between networks, and various common application service problems. For example, DHCP dynamic address allocation service, HTTP(s) web service, DNS domain name resolution service, FTP file transfer service, and EMAIL service. The main purpose of the comprehensive experiment is to allow students to comprehensively use a variety of technologies, methods and tools from the perspective of the network system as a whole, on the basis of the design experiment, for the analysis, design and implementation process of complete network system solutions, and to cultivate the ability to solve complex network engineering problems.

3.2.2. Multi-level Experimental Design

Integrating OSI/RM and TCP/IP network architectures, a five-layer principle model suitable for teaching is established, from the bottom up to the physical layer, data link layer, network layer, transport layer and application layer. Therefore, the experimental content is organized according to the five-layer principle model. However, unlike the traditional teaching concept, the purpose of the experiment is not only the knowledge level, but also emphasizes the cultivation of students' ability and the improvement of quality.

Under the traditional teaching concept, experiments are generally organized independently according to hierarchical knowledge, without considering the relationship between hierarchical knowledge, not reflecting the overall working process of the network, and not understanding the project practice process from the perspective of network engineering projects. Therefore, choose a complete network engineering project requirement, such as a campus network or enterprise network, design a large topology, and determine that it covers all levels of knowledge. The verification, design and comprehensive experiments of each layer are completed progressively under the same topology and project requirements, from the physical layer to the application layer, from the LAN to the WAN, from wired to wireless, from intra-network communication to inter-network communication, from solving communication requirements to application requirements, etc. Enable students to complete the requirements analysis, topology design, equipment deployment, and debugging of complete network engineering projects.

3.3. Design of Evaluation Criteria

The concept of engineering education professional certification requires the evaluation of the competency requirements described in the course objectives based on the output results. The purpose of evaluation is not only to prove that the course goals have been achieved, but also to check the quality of the output, identify problems, analyze the causes, and continuously improve. Since evaluation is to be carried out, the design of evaluation standards is crucial. The design of evaluation standards is comprehensively considered from three perspectives.

(1) Final evaluation

The learning results generally include experimental topology files, packet files, and experimental reports. Final evaluation should be performed for each experiment. The evaluation criteria include three aspects: accuracy, completeness and standardization.

Accuracy refers to the accuracy of evaluating the output from the aspects of experimental steps, operations, configurations, tests, analysis and conclusions.

Completeness refers to the completeness of the output from the aspects of experimental content, experimental topology and experimental process.

Normativeness evaluates the standardization of output results from the aspects of experimental information filling, text format, and chart description.

(2) Formative evaluation

A complete experimental process should include pre-experiment preparation, experimental operation process and post-experiment summary, as well as experimental attitude. In addition to the final evaluation, each experiment should also be formatively evaluated from the above processes and performances.

Before the experiment, prepare to evaluate whether students can preview the experimental content and design a preliminary experimental plan; whether the basic information, purpose and content of the experiment can be filled in in a standardized manner; Whether the experimental software and hardware environment can be prepared.

The experimental operation process evaluates whether the students' experimental records meet the accuracy, completeness and standardization requirements of the experiment.

After the experiment, summarize and evaluate the students' experience in experimental technology and non-technical aspects, and understand the students' self-evaluation of whether the expected results of the experiment have been achieved.

Experimental attitude evaluates students' attendance and discipline.

(3) Multi-level evaluation

The competency requirements described by different course objectives are different, which is reflected in verification, design and comprehensive experiments without types, and the experimental objectives describe the ability requirements at different levels. Therefore, the evaluation of different levels of competency requirements needs to design multi-level evaluation standards.

Confirmatory experimental evaluation requires students to be able to imitate, reproduce, interpret and verify the experimental content related to network principles and software tools.

Design experimental evaluation requires students to be able to perform functional analysis, topology design, equipment configuration and troubleshooting testing on network function-related experimental content.

Comprehensive experimental evaluation requires students to be able to comprehensively apply the knowledge and tools they have learned for the experimental content related to complex network engineering projects with specific backgrounds, and complete the standard processes of network engineering projects such as requirements analysis, equipment selection, link linking, address planning, equipment deployment, operation and maintenance debugging and document writing through problem analysis, scheme design and project implementation, and evaluate students' ability to solve complex engineering problems.

4. Implementation of Experimental Teaching

4.1. Experimental Environment

The experimental environment adopts a combination of virtual and real methods. The physical LAN environment of the laboratory is used to support intranet communication through switches and external network communication through routers. Deploy emulator and virtual machine software such as Cisco Packet Tracer, eNSP, GNS3, EVE-NG, PNETLAB, VirtualBox, and VMware Workstation on end devices to build a virtual network environment, which can support network types such as LAN and WAN, wired and wireless, and network devices such as switches, routers, firewalls, wireless controllers, and servers. Network functions such as switching, routing, security, wireless, and application services are supported. Considering the current cost of hardware configuration and software usage for student computers, Cisco Packet Tracer, GNS3, and VirtualBox are recommended.

Cisco Packet Tracer is a free network simulator software for Cisco Networking Academy students that simulates Cisco networks, ideal for network beginners and CCNA certifiers, but does not support emulating Cisco hardware or real system images from Cisco or other vendors [13].

GNS3 is an open-source and free network emulator software that provides a graphical client and virtual machine server, which can simulate and emulate various types of device hardware, run real system images, and support the number of devices limited by CPU and memory resources[14]. If resources are sufficient, it is recommended to use GNS3 to complete experiments with network hardware devices that are not supported by Cisco Packet Tracer.

VirtualBox is Oracle's free and open-source virtualization product for enterprises and individuals, supporting a large number of Windows and Linux guest operating systems[15]. It is recommended to use VirtualBox to deploy a Windows or Linux server to complete the Cisco Packet Tracer does not support web application service experiments.

Under normal circumstances, computer network courses are for freshman students, and students lack computer thinking and practical skills. In order to facilitate students to conduct experiments anytime and anywhere, it is recommended to use Cisco Packet Tracer for teaching, considering the current mainstream notebook hardware configuration. The software itself and Cisco Network Academy provide rich learning resources, and general LAN, WAN, switching, routing, wireless, security, and application service experiments can be completed within the software. Advanced complex experiments with special hardware equipment and application service requirements are performed using GNS3 and VirtualBox.

4.2. Experimental Examples

As a complex network engineering problem, the network topology and functional requirements are designed, covering all knowledge, and all functional requirements are progressively completed under the same network topology through different types of experiments.

The network topology of the campus network is shown as Figure 1.

The functional requirements are as follows:

(1) There is one main campus, one branch campus and one living area, which are accessed through the frame relay network.

(2) The frame relay network realizes fast communication between the main campus, branch campus and centralized dormitory area.

(3) Configure dynamic and static routing to communicate between various regions.

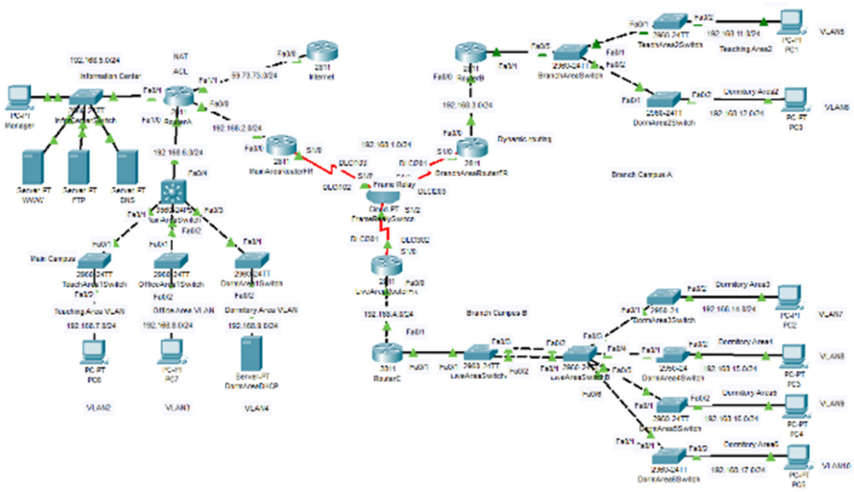

Figure 1. Network Topology of Campus Network

(4) The main campus includes teaching area, office area, information center and dormitory area one.

The teaching area is defined as one VLAN, which is accessed through a high-level switch and the host address is statically assigned.

The office area is defined as one VLAN, which is accessed through a high-level switch, the host address is statically assigned, the sticky secure MAC address is activated, the maximum number of secure MAC addresses and the overrun handling rules are set.

Dormitory area one is defined as one VLAN, accessed through a high-level switch, and the host address is statically assigned.

Teaching areas, office areas, and independent dormitory areas realize inter-VLAN communication through high-level switches;

The information center is defined as one physical LAN, which is statically assigned server addresses, provides WEB services on campus and off-campus, and only provides FTP services and DNS services on campus, and connects to the Internet for NAT conversion.

(5) The branch campus includes the teaching area and the independent dormitory area.

The teaching area is defined as one VLAN, and the host address is statically assigned.

An independent dormitory area is defined as one VLAN, and the host address is dynamically assigned.

The teaching area and the independent dormitory area realize inter-VLAN communication through a single-arm router.

(6) The living area includes multiple dormitory areas, each dormitory area is defined as one VLAN, dynamic address allocation, VLAN management through VTP, and VLAN load sharing through STP.

Follow section 2.2.2 to complete different types of experiments from the physical layer to the application layer. Cultivate students' ability to analyze requirements, design topology, deploy equipment, debug and troubleshoot and write documents in the process of solving network engineering problems.

4.3. Experimental Effect

According to the requirements of academic performance management and graduation credits, the achievement standard of the course objectives is determined to be 0.66 or above.

All students majoring in network engineering in a certian grade were evaluated for achieving course goals. The scatter plot of all course objectives is shown as Figure 2-6, with the abscissa representing the student's serial number and the ordinate representing the degree of achievement of the course objectives, with a baseline of 0.66.

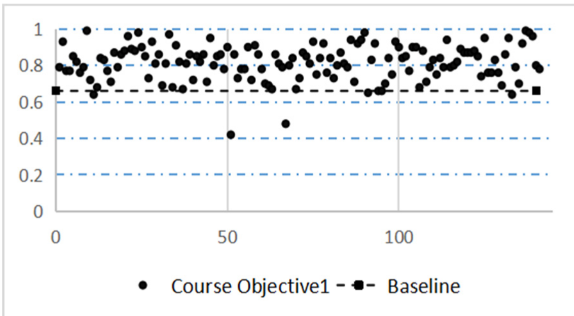

Figure 2. Scatter Plot of Course Objective 1

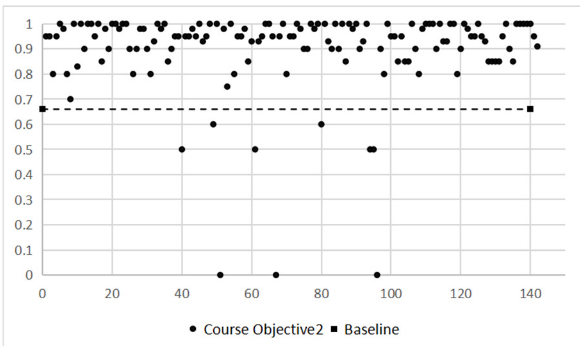

Figure 3. Scatter Plot of Course Objective 2

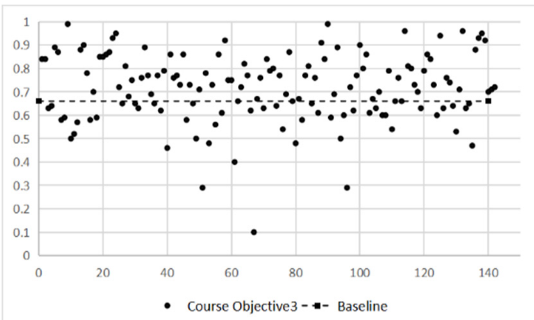

Figure 4. Scatter Plot of Course Objective 3

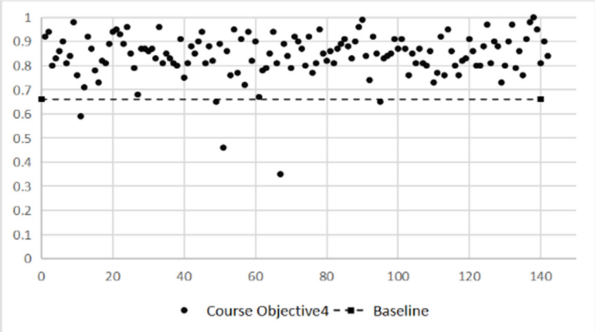

Figure 5. Scatter Plot of Course Objective 4

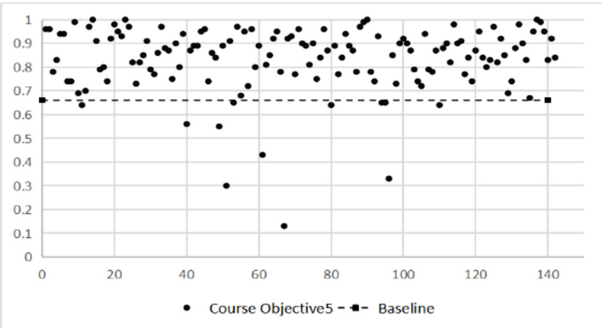

Figure 6. Scatter Plot of Course Objective 5

Most of the students achieved all the course objectives, indicating that the overall effect of the experimental teaching of computer network courses under the concept of engineering education certification is good. For the problem that some students have not achieved the curriculum goals, the reasons for the teaching process are found and analyzed through the students' personal evaluation data, and the next teaching improvement plan and measures are put forward for continuous improvement. In accordance with the educational concept of engineering education professional certification, the next round of course experimental teaching and course objective evaluation will be carried out, and a continuous improvement mechanism will be established to gradually improve the quality of course experimental teaching.

5. Conclusion

Following the concept of student-centered, outcome-oriented education and continuous improvement certified by engineering education, this paper analyzes the existing problems of emphasizing teaching over learning, low level of learning outcomes, and lack of continuous improvement mechanism for the experimental teaching of computer network courses. It proves that the experimental teaching reform of computer network courses under the concept of engineering education professional certification is feasible and effective.

References

[1] Dai Xianzhong. Re-understanding of the Accreditation Standards for Engineering Education Majors[J].China University Teaching,2022(11):4-11.

[2] Zhu Lu, Hu Dexin, He Zhen, Gu Peihua. The Development and Reform of the International Engineering Education Accreditation System: A Comparative Analysis Based on the Washington Agreement and the European Engineering Education Accreditation System[J].Higher Engineering Education Research,2022(04):38-51.

[3] Zhu Lu, Wang Geng, Hu Dexin, Yan Guangfen, Gu Peihua. International case study of engineering education professional accreditation standards[J].Higher Engineering Education Research,2022(03):32-45+73.

[4] Wang Geng, Zhu Lu, Hu Dexin, Yan Guangfen, Gu Peihua. International Comparative Study on Engineering Education Accreditation Standards[J].Higher Engineering Education Research,2022(02):35-44.

[5] Cui Wei, Pang Xiaoli. Student-centered Curriculum Evaluation System Design and Practice[J].Journal of Higher Education, 2023, 9(02):96-101.

[6] Ou Jun, Wu Fugen, Yang Wenbin. Laboratory Research and Exploration,2021,40(07):209-212+224.

[7] Ma Huizi, Miao Xuan, Wang Xiangrong, Liu Meijuan. Laboratory Research and Exploration,2022,41(09):223-228.

[8] Song Yue, Chen Xiangping, Hu Sheng, Ren Bin. Laboratory Research and Exploration,2021,40(02):215-217.

[9] Zhang Hui, Huang Fengli, Li Jiwu, Wang Qingquan. Laboratory Research and Exploration,2020,39(07):219-222.

[10] Zhang Huiping, Zhu Kai. Research on the feedback mechanism of curriculum teaching quality monitoring based on continuous improvement[J].Innovation and Entrepreneurship Theory and Practice,2022,5(12):45-47.

[11] Xu Haixia, Zhou Wei. Research and Practice of Continuous Improvement in Engineering Education Professional Accreditation[J]. Higher Science Education,2022(04):102-108.

[12] Wang Yanxia, Li Peng, Deng Yuechuan, Tu Jinsheng. Research on Continuous Improvement of Curriculum Based on Bloom's Classification of Educational Objectives[J].Journal of Yulin University,2022,32(02):59-63.

[13] Liao Boxun. Exploration on Practical Teaching Methods of Computer Communication and Network Courses Based on Packet Tracer in the Context of New Engineering[J].Digital Technology and Application,2022,40(12):56-58.

[14] Peng Yulan, Dai Qiyi, Li Jiarui, Li Zonglei. Modern Information Technology,2022,6(18):185-187+191.

[15] Pan Jingfeng, Tang Zhikai, Mao Geng, Deng Shuaiya. Construction and Application of Information Teaching Platform Based on VirtualBox Virtual Machine Technology[J]. Industrial and Information Education,2019(08):69-72.