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Teaching Design and Practice of Capstone Courses for Electronic Information Majors

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Abstract: Against the background of engineering education reform, electronic information majors urgently need to construct a comprehensive, practical and innovative curriculum system to cultivate students' ability to solve complex engineering problems. As a core carrier integrating multidisciplinary knowledge and connecting theory with industrial practice, the teaching design of Capstone courses directly affects the quality of talent training. Based on the Outcome-Based Education (OBE) concept and drawing on the logic of "capstone courses" in American engineering and technology universities, this paper constructs a teaching system for Capstone courses of electronic information majors from four dimensions: curriculum goal positioning, content system construction, teaching mode innovation, and evaluation mechanism optimization. Taking the "Comprehensive Professional Experiment" as a practical carrier to verify its feasibility, this study provides a reference for similar curriculum reforms in application-oriented undergraduate universities.

Keywords: Capstone course; Engineering education accreditation; Application-oriented undergraduate universities

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1. Background

With the rapid iteration of the new generation of information technology, the demand for talents in the electronic information industry presents the characteristics of "compound, innovative, and practical." The Engineering Education Accreditation Standards (2024 Edition) clearly requires that majors should cultivate students' ability to comprehensively apply mathematics, natural sciences and professional knowledge to solve complex engineering problems. However, traditional professional courses have problems such as a disconnection between theory and practice and insufficient interdisciplinary integration, which make it difficult to meet industrial needs and accreditation standards [1].

Originating from American engineering and technology universities, Capstone courses are core positioned to "integrate prior professional knowledge and solve practical engineering problems," realizing the transformation from "knowledge mastery" to "ability output," while taking into account the cultivation of non-technical literacy such as communication skills, ethical responsibility and cost control [2]. Foreign Capstone courses have formed a mature teaching model. Most American universities adopt an industry-real-problem-oriented approach and carry out teaching through interdisciplinary team cooperation and school-enterprise joint guidance. The undergraduate Capstone courses of top universities such as the Massachusetts Institute of Technology (MIT) and Olin College of Engineering are mostly characterized by interdisciplinarity, high authenticity and cutting-edge nature, and implement a project-centered multi-participation framework in the implementation process [3–5]. Through interdisciplinary case analysis, Lee confirmed the core role of Capstone courses in cultivating students' problem-solving ability and team cooperation ability, and emphasized the need to supplement differentiated ability training goals according to professional characteristics [6].

Drawing on the concept of Capstone courses in foreign universities, many domestic universities have been promoting the construction of Capstone courses in recent years. Taking the construction of emerging engineering in local universities as the background, Wang Jianjun proposed a "four-in-one" implementation model for comprehensive practical courses [7]. Deng et al. verified the effectiveness of teaching reform based on the Capstone concept in improving students' system design and innovation capabilities, but the curriculum content was not closely combined with industrial reality [8]; Rao Lan et al. found in the reform of comprehensive curriculum design that project-based teaching can effectively improve students' engineering practice ability, but the evaluation mechanism needs to be further optimized [9].

This paper aims to address the design of Capstone courses for electronic information majors in application-oriented undergraduate universities, and explore how to align with engineering education accreditation standards and establish a scientific evaluation mechanism.

2. Design goals and principles of capstone courses

2.1. Curriculum design goals and content

The goal of Capstone courses for electronic information majors in application-oriented undergraduate universities is to cultivate engineering thinking on the basis of technical ability training, enabling students to analyze and solve problems from multiple dimensions such as technology, economy and society [10,11]. The design content includes:

(1) Clarify the mapping relationship between curriculum goals and graduation requirements;

(2) Design a curriculum content system of "interdisciplinary integration + real project-driven";

(3) Innovate a teaching implementation model of "school-enterprise collaboration + team cooperation + progress control";

(4) Establish a quality assurance mechanism of "formative evaluation + diversified feedback" [12].

2.2. Core principles of curriculum design

(1) Real Project-Driven Principle: Based on enterprise engineering cases, select industrial hot issues as curriculum projects, simulate the complexity, time constraints and economic cost limitations of real engineering scenarios, and improve students' ability to solve practical problems.

(2) Interdisciplinary Integration Principle: Integrate multidisciplinary knowledge such as electronic technology, intelligent information processing, computer programming and data analysis, and incorporate basic content of project management and economics to cultivate students' ability to comprehensively apply cross-disciplinary skills to solve complex problems [13].

(3) Continuous Improvement Principle: Establish a closed-loop mechanism of "content design - teaching

implementation - effect evaluation - feedback optimization," dynamically adjust curriculum content and teaching methods according to students' performance and tutors' feedback during the course, and ensure the continuous improvement of curriculum quality.

3. Curriculum teaching design framework

3.1. Curriculum goal positioning: Aligning with industrial needs and professional characteristics

According to the professional curriculum system and the characteristics of Capstone courses, integrate content related to engineering awareness training, and establish the mapping relationship between curriculum goals and graduation requirement observation points [14], as shown in **Table 1**.

Table 1. Correspondence between graduation requirements and curriculum goals

Graduation requirement observation points	Curriculum goals
Design/Development	Be able to design electronic information systems that meet specific needs, reflecting innovation and feasibility, while considering various social constraints.
Team Collaboration	Be able to assume roles in interdisciplinary teams, communicate and cooperate effectively, and complete assigned tasks.
Project Management and Economic Decision-Making	Be able to reasonably plan project progress and team division of labor, control progress within the practice cycle; be able to conduct cost budget accounting and carry out program cost-benefit analysis.
Engineering Ethics and Professional Norms	Abide by industry ethics and legal norms, and establish a sense of responsibility and cost-saving awareness.

3.2. Curriculum content system: Modular design based on courses

Adopt an organizational method of "modularization + projectization" to construct a three-level content system of "basic module - core module - extended module."

3.2.1. Basic module

Covers content such as engineering ethics and professional norms, basic project management (WBS task decomposition, Gantt chart drawing), economic decision-making methods (benefit analysis, budget accounting), and technical research methods.

3.2.2. Core module: Divided into four sub-modules

(1) Project Approval and Program Design: Team formation (3–5 people/team), topic selection and demonstration (combined with industrial needs), technical route planning, feasibility analysis (including economic evaluation, such as hardware cost budget), and completion of thesis proposal;

(2) System Development and Implementation: Hardware selection and development (balancing performance and cost), software programming and debugging, system integration and testing, synchronous recording of project progress, and control of time nodes using Gantt charts;

(3) Outcome Optimization and Improvement: Improve the program based on test results and economic feedback to enhance system performance and stability;

(4) Outcome Display and Defense Preparation: Write research reports, produce demonstration prototypes,

and conduct internal pre-defense.

3.2.3. Extended module

Combine cutting-edge industrial trends to set special lectures on artificial intelligence applications, green low-carbon technologies, etc., to expand students' professional horizons and thinking. Encourage students to integrate new technologies (such as edge computing) into program design.

3.3. Teaching implementation model: "Dual-Tutor System + Four-Stage Cycle + Progress Control"

(1) Dual-Tutor Formation: On-campus professional teachers are responsible for theoretical guidance, process management and project management teaching; enterprise technical experts are responsible for engineering practice guidance, industrial demand connection and economic decision-making comments.

(2) Four-Stage Teaching Process [15]:

(A) Stage 1: Curriculum Planning and Project Approval. Students form teams based on the principle of complementary advantages, determine project themes under the guidance of dual tutors, complete literature research and program design (including economic analysis), and clarify the progress plan (in the form of Gantt charts);

(B) Stage 2: Project Implementation and Process Guidance. Teams divide labor and cooperate, hold daily meetings to report progress and solve problems; tutors provide precise guidance through on-site or online methods, focusing on technical difficulty breakthroughs, project progress control and cost control;

(C) Stage 3: Outcome Optimization and Display Preparation. Teams complete system testing and optimization, improve project reports, and produce demonstration prototypes and defense materials;

(D) Stage 4: Outcome Evaluation and Feedback. Conduct outcome acceptance through public defense, work display and other forms; dual tutors and peer experts jointly comment, focusing on feedback on the feasibility of technical programs, project management effectiveness and rationality of economic decisions, and form improvement suggestions.

(3) Progress and Cost Control Measures: Establish a mechanism of "daily progress check-in + mid-term cost verification", requiring teams to update progress daily and submit cost accounting forms in the mid-term; enterprise tutors evaluate cost control to avoid exceeding the budget.

3.4. Evaluation mechanism optimization: "Three-Dimension, Multi-Subject Evaluation"

3.4.1. Evaluation dimensions and weights

(1) Process Performance (40%): Including project participation, team contribution, completeness of technical documents, and effectiveness of project progress and cost control, scored by on-campus tutors based on daily progress records and mid-term verification results;

(2) Outcome Quality (40%): Covering system function realization, technical innovation, economic rationality and report standardization, jointly scored by dual tutors, with enterprise tutors focusing on evaluating economic decision-related indicators;

(3) Defense Performance (20%): Including oral expression, logical thinking, outcome display effect and question response.

3.4.2. Multi-subject evaluation

Introduce a multi-subject evaluation system of "student self-evaluation + team mutual evaluation + enterprise tutor evaluation + on-campus tutor evaluation". Among them, enterprise tutor evaluation focuses on the standardization of project management and the scientificity of economic decision-making; student self-evaluation and team mutual evaluation need to include reflections on their own and the team's progress control and cost awareness to ensure the objectivity and comprehensiveness of evaluation results.

3.4.3. Continuous improvement mechanism

Link evaluation results with curriculum optimization, and incorporate curriculum evaluation data into graduation requirement achievement analysis. Collect student feedback and enterprise suggestions, dynamically adjust curriculum content and assessment methods, and form a closed-loop management of "evaluation - feedback - improvement".

4. Practical case and effectiveness analysis of "Comprehensive Professional Experiment" in electronic information engineering major of our university

The "Comprehensive Professional Experiment" is a 3-week Capstone course in the second semester of the junior year. Taking the 2024 autumn semester project "Development of an Intelligent Warehouse Monitoring System Based on the Internet of Things" as an example, the project was completed by a team of 4 students: the team decomposed tasks using WBS tools, planned the 3-week progress through Gantt charts, and updated the progress account daily; in the program design stage, the team compared two schemes, "STM32-based" and "Loongson 1C102-based", conducted cost-benefit analysis from three dimensions of hardware cost, development cycle and later maintenance cost, and finally selected "Loongson 1C102-based"; when "hardware procurement costs exceeded the budget" was found in the mid-term, after team discussion and tutor guidance, the scheme of "replacing low-cost sensors" was adopted, and the total cost was finally controlled within the budget; the project successfully realized the core functions of the system, and the team clearly expounded the progress control and cost optimization ideas in the defense, winning unanimous praise from the defense committee.

Through the curriculum quality evaluation of the "Comprehensive Professional Experiment" in this semester, it was found that students performed well in project management and economic decision-making abilities. 90% of students could independently use Gantt charts to complete project progress planning, 78% of students could achieve cost control in the project, and students' engineering thinking and innovation abilities were significantly improved, which strongly supported the achievement of graduation requirements.

However, the course still has the following problems: first, some projects have a gap with engineering reality; second, the 3-week intensive practice cycle is relatively short, resulting in great pressure on progress control for some complex projects. In the next teaching cycle, improvements need to be made in optimizing teaching content and flexibly adjusting the cycle.

5. Conclusion

The Capstone course constructed in this paper takes "basic-core-extended" as the content module, adopts the implementation model of "dual-tutor system + four-stage cycle + progress control", and strengthens school-enterprise collaboration and process management; with "three-dimension, multi-subject" as the evaluation mechanism, it effectively supports the training goals of students' engineering practice ability, team cooperation ability, project management and economic decision-making ability. It provides replicable and promotable experience for the reform of Capstone courses for electronic information majors in application-oriented undergraduate universities.

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Disclosure statement

The authors declare no conflict of interest.

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