World Journal of Educational Studies
Print ISSN: 2959-9989
Online ISSN: 2959-9997
DOI: https://doi.org/10.61784/wjes3158

APPLICATION OF THE INTEGRATION OF PROFESSIONAL AND INNOVATIVE APPROACHES IN THE COURSE "COMPUTER ORGANIZATION AND ARCHITECTURE"

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Abstract: Taking the integration of specialty education with innovation and entrepreneurship education (specialty-innovation integration) as an opportunity, this paper analyzes the existing problems in the current teaching process of the "Computer Organization" course from three aspects — teachers, students, and the curriculum system. Through five measures — improving teachers' professional competence, introducing innovative practical components, restructuring the course content, improving teaching methods, and reforming evaluation methods — innovation is integrated into the course. As a result, the teaching effectiveness has been enhanced, with equal emphasis on knowledge and innovation, mutual enhancement of intellect and ability, and adherence to fundamental principles while pursuing innovation. This provides ideas for cultivating interdisciplinary talents in the new era.
Keywords: Engineering education accreditation; Computer organization; Goal achievement; Continuous improvement

1 INTRODUCTION

The integration of professional education and innovation has garnered significant attention in the education field today, becoming a core driving force for educational progress. Deep integration of professional education with innovation and entrepreneurship, emphasizing both knowledge and innovation, fostering mutual growth in intelligence and ability, and upholding integrity while innovating, is essential to keeping pace with the times, cultivating well-rounded talents for the new era, meeting the needs of social evolution, empowering industrial development with knowledge, enhancing employment competitiveness, and becoming a powerful booster for industrial upgrading.

Computer Organization Principles is a compulsory subject for postgraduate entrance examinations in computer science majors across the country. It is a core foundational course for computer science majors to build a computer science knowledge framework [1]. It is a basic means to master the internal structure, functional characteristics and working principles of a single processor. It is also one of the core technologies for deeply understanding the mechanism of hardware and software collaboration and optimizing the kernel to write high-quality code. It is a core professional course set by the "Professional Talent Training Program for Computer Science and Technology" [2]. However, the course is characterized by its complex concepts and strong theoretical nature [3]. Although the course team has spent a lot of energy reforming the talent training model over the long term, it has always been unable to get rid of the rigid teaching content, insufficient cultivation of innovative hands-on ability and single assessment method in the training model. The indoctrination teaching and the score-based evaluation have resulted in insufficient innovation motivation among students and difficulty in fundamentally improving the teaching quality [4]. Therefore, it is very necessary to combine the professional innovation integration with the Computer Organization Principles course for research.

2 EXISTING PROBLEMS IN TEACHING

2.1 Teacher's Side

The teaching method is monotonous and the indoctrination teaching with low student participation cannot mobilize students' learning enthusiasm and initiative [5]. It cannot guide students to explore the connection between various subsystems of computer hardware and how to make innovative applications in practice. It is difficult to cultivate students' innovative thinking and practical ability, which is not conducive to students building a complete computer knowledge system. It is also inconsistent with the current social goal of cultivating innovative computer professionals [6].

2.2 Student Perspective

Firstly, students lack a solid grasp of hardware knowledge: The course requires students to have a good foundation in prerequisite courses such as digital circuits, analog circuits, and programming languages. In reality, students have not deeply understood these prerequisite courses, leading to difficulties in understanding or even gaps in their comprehension when encountering topics such as the application of basic logic devices, building circuits to realize the functions of computer components, and using programming knowledge such as assembly language to understand the specific execution process of the instruction system. Secondly, students lack motivation to learn actively: The content of the Computer Organization and Architecture course is abstract, and the concepts and principles are complex. For example, the various addressing modes in the instruction system and the workflow of microprogram controllers cannot be intuitively grasped. Students need to build an operational mechanism model in their minds through abstract thinking, which is quite difficult. Unlike software courses where students see the operational effects and feel a sense of accomplishment, hardware learning is tedious and can easily wear down students' interest and confidence, making "preferring software and fearing hardware" the norm. Students lack the ability to apply theory to practice: When using hardware principles to solve practical problems, such as optimizing and improving the design of a circuit for a certain subsystem inside a computer, students are at a loss, and there is a serious disconnect between theory and practice.

2.3 Curriculum System

The curriculum system lacks innovative practical projects, does not incorporate innovation and entrepreneurship elements [4,6], lacks a connection between professional knowledge and innovative practice, fails to stimulate innovative thinking, and limits the ability to carry out innovative practices using computer organization principles. As a result, the quality of course teaching does not reach a satisfactory level and does not meet the social demand for innovative talents in the field of computer science.

3 PROJECT IMPLEMENTATION

3.1 Improvement of Teachers' Professional Competence

Although the course instructors all have many years of experience teaching "Computer Organization and Architecture" and are very familiar with the knowledge points involved, they still need to delve deeper and learn how to expand the teaching content in both depth and breadth, innovate teaching methods, and integrate innovation and entrepreneurship thinking into the course. Relying on the basic teaching organization of computer architecture, and making full use of holidays and spare time, the instructors diligently studied online courses offered by many well-known universities, various innovation and entrepreneurship competitions, and carefully read hundreds of teaching research papers related to innovation and entrepreneurship. Through this learning, the course team gained the following.

3.2 Introducing Innovative Practice Sessions

The implementation of practice sessions can not only improve practical skills and engineering application skills, but also cultivate students' ability to learn independently, think independently, consult materials, work in teams and give full play to their initiative in the process of designing systems and solving problems, enhance their self-confidence and stimulate their innovative awareness [7,8].

Practical teaching employs real hardware design methods, allowing students to apply theoretical knowledge to practical situations. This fosters a sense of satisfaction and confidence from the results, helping to stimulate students' interest in learning. However, due to the long development cycle, the depth and breadth of knowledge involved, the complexity of the content, and the need for a strong foundation of prior knowledge, the practical implementation process is quite challenging. But we cannot give up because of these difficulties. After discussion, the course team decided to adopt a "step-by-step – focusing on key points – multi-level" strategy. "Step-by-step" means dividing practical teaching into several stages; "focusing on key points" means designing key modules; and "multi-level" refers to the progressively increasing difficulty and reusability of the results.

The specific implementation process is as follows:

Phase 1: "Subtle Influence" --- Integrating practical design concepts into teaching, introducing some ideas and knowledge involved in the design implementation process into the classroom, and guiding students to conduct analysis and simple design.

Phase 2: "Exemplary Leadership" --- Organize a group of outstanding students to carry out design practice. Through the exemplary role of these students, eliminate the fear of difficulties among other students and inspire their self-confidence. At the same time, these students can also serve as the teacher's capable assistants to help guide other students.

Phase 3: "Summary and Adjustment" --- Summarize the achievements of this phase and further improve the phase. In this phase, the course team teachers conduct detailed exchanges and summaries of the work carried out in the early stage and formulate a plan for large-scale promotion.

Phase 4: "Promotion and Implementation" - Large-scale implementation phase. Based on the experience accumulated in the early stage, students will carry out practical teaching and design and implement a whole from the underlying hardware to the upper-level machine instruction execution.

3.3 Reorganize the Course Content

Develop more reasonable teaching objectives, content, requirements, methods, and assessment methods that reflect the three dimensions of knowledge, ability, and innovation.

The course objectives and specific content are shown in Table 1:

Table 1 Course Objectives and Specific Content

	Target	Innovation Projects
Theoretical teaching objectives	Objective 1: To be able to apply knowledge of data representation and computation to reason and analyze engineering performance and select appropriate data types and computation methods during the development of complex engineering problems in the field of computer applications; to be able to perform system analysis based on requirements for access speed, cost, and capacity and select appropriate types of memory; and to be able to analyze and design microinstructions for a given hardware system and instruction cycle flowchart. Objective 2: To comprehensively apply knowledge of data representation, instruction sets, memory read/write, and microprogrammed controllers, considering constraints such as public health and safety, energy conservation and environmental protection, law and ethics, and social and cultural factors from a systems perspective, and to provide overall solutions to complex engineering problems in the field of computer applications; to design and implement a memory expansion circuit system framework that meets word count and bit length requirements; and to design software programs and corresponding system hardware microinstructions that conform to the working principle of memory hierarchical structures. During the design process, different approaches can be attempted to demonstrate innovation .	➢ This project designs and implements an arithmetic logic unit (ALU) capable of performing 16-bit binary data operations using two 74181 chips. The main concepts covered in this project include parallel carry, function control signals, and timing . ➢ This section covers memory design, utilizing SRAM and ROM to create storage spaces that meet address allocation requirements. The main topics include chip select signal generation circuit design, address line and data line circuit design, and read/write control signal design. ➢ The relationship between programs, instruction cycles, and microprograms. Microprogrammed controllers and microprogram design: Based on given arithmetic logic unit (ALU), controller, memory hardware circuitry, microinstruction format, and instruction cycle flowchart, design and implement microinstructions ; ➢ Design several machine instructions, and based on the computer hardware architecture and microinstruction format, write the corresponding microinstruction sequence, and then debug it on the machine. This topic mainly covers the following knowledge points: hardware and software relationships, and the low-level execution process of machine instructions.
Experimental teaching objectives	Objective: To be able to be familiar with the functional characteristics and usage methods of the devices used in experiments such as full adders, arithmetic function generators, random access memory, microprogrammed controllers, and the relationship between microinstructions and machine instructions; to design experimental schemes according to experimental requirements; to complete experimental operations; and to analyze and solve problems encountered during implementation.	➢ Design an arithmetic unit operation experiment with overflow results; design an arithmetic unit experiment that can perform multiplication and division operations using the 74LS299 chip; design an experiment to write and read data into unused space of the 6116 memory; be able to design experimental schemes, solve problems, and complete experiments.

3.4 Improvement of Teaching Methods

(a) In-depth classroom lectures, physical demonstrations, and multimedia courseware animation simulations: Stimulate students' learning interest and enable them to master fundamental knowledge of computer system architecture, such as the arithmetic unit's operation process, memory read/write process, CPU instruction fetching and execution process, and bus systems; assign innovative project cases, and guide students to master relevant knowledge and methods through case analysis and discussion, and how to apply this knowledge to system design and development. Students are required to collect relevant resources using information technology outside of class, and their work will be assessed through assignments to achieve the requirements of Course Objective 1.

(b) Using innovative case studies with a certain degree of complexity: Conduct functional analysis to help students understand how to apply theoretical knowledge to solve practical problems. For topics such as the principle of locality, the principle of pipeline interruption, memory data read/write rules, and the implementation principle of cache memory, the classroom teaching focuses on explaining from a system perspective how the composition and working principles of computer hardware constrain program execution efficiency, and how to design programs to be consistent with the computer hardware structure to improve code quality. Appropriately challenging exercises are assigned in class, requiring students to independently find relevant information, solve problems through self-study, and be assessed through assignments.

The course adopts an innovative project-driven teaching approach, setting different projects and requirements for students with varying abilities. Projects are mainly divided into two categories: in-class research projects and open-ended large-scale projects after class. In-class research projects consist of 3-4 comprehensive training projects of moderate difficulty. These projects cover both basic course knowledge and cutting-edge knowledge. Students plan their time independently, consult relevant literature, work in groups, analyze and design projects, determine project development plans, and finally submit project results for discussion with teachers and students. These projects are designed to ensure students master the basic course knowledge while enhancing their academic research abilities. The projects require students to deeply understand the relevant classroom theories while cultivating self-learning, problem-solving, teamwork, and innovation skills. The implementation of in-class projects enhances learning interest and fosters a sense of participation, self-worth, and fulfillment. For over a decade, students have learned in the traditional teacher-lecturing, student-listening style. Even small changes in teaching methods can yield unexpected results, bringing surprises and satisfaction to teachers. They genuinely marvel at how capable their students can be when given the opportunity to take initiative. Through teaching students from the School of Information Science and Technology and the School of Modern Science and Technology over the past few years, it has been observed that students from the School of Modern Science and Technology demonstrate stronger participation, more active thinking, and the most impressive achievements. Some students not only presented relevant knowledge but also used it to explore the history and development of related industries, analyzing employment prospects, salaries, and potential employers. They also offered career advice to their classmates, outlining which courses to focus on, what extracurricular learning to acquire, and which industries and companies to pay attention to for recruitment information. Their clear and logical thinking is truly admirable.

The main purpose of conducting after-school large-scale projects is to further guide capable and interested students through practical projects, and to further stimulate the integration of theoretical knowledge and independent innovation ability through participation in project development. The main after-school large-scale projects are shown in Table 2:

Table 2 Post-class Research Projects

Project Content	
Project 1 : Design and Implementation of an Internet of Things-Based Rural Water Supply Environment Monitoring System	
Project 2 : Design and Implementation of a Multi-Point Leakage Monitoring System for Water Supply Network Based on the Internet of Things	Sensors are used to monitor water quality parameters (pH, dissolved oxygen, turbidity, ammonia nitrogen, etc.), water level, temperature, pressure, and flow rate. The collected data is transmitted to a cloud server and displayed on a mobile device. When the monitored values exceed the set range, the microcontroller alarm circuit triggers an audible and visual alarm.
Project 3: Remote Real-time Monitoring System for Aquaculture Environment.	Sensors are used to monitor indicators such as vibration, water pressure, and water flow in the water supply pipeline. The collected data and location information are transmitted to a cloud server, and the values are displayed on a mobile device. When the monitored values exceed the set range, the microcontroller alarm circuit will trigger an audible and visual alarm.
Project 4: Automatic Irrigation Control System for Farmland	Equipped with cameras or sensors to collect data from multiple points, the device can remotely control or automatically generate lasers to remove weeds if they become too dense, based on IoT communication technology. The movement of the weeding device can be controlled.
Project 5: Smart Wardrobe System	Sensors are used to monitor data indicators such as soil moisture, pressure, soil pH, and soil electrical conductivity. The collected data and location information are transmitted to a cloud server and the values are displayed on a mobile device. When the monitored values exceed the set range, the microcontroller alarm circuit will issue an audible and visual alarm. At the same time, timed irrigation and remote automatic irrigation are also realized.
Project 6: Chicken Feed Mold Monitoring System	This system enables multi-point temperature and humidity detection within a wardrobe, displaying temperature, humidity, and time, as well as dehumidification and disinfection functions. It consists of a display module, a temperature and humidity detection module, a button module, an alarm module, a clock module, and a cooling and dehumidification module. The system uses the temperature and humidity detection module to measure the temperature and humidity inside the wardrobe and compares this information with preset values via a microcontroller. When the temperature or humidity exceeds the preset values, dehumidification and disinfection will be initiated, and an alarm will sound. The button module is used to update the current time, and the time, temperature, and humidity will be displayed on the screen.
Project 7: Egg Traceability System	This system enables the detection, monitoring, and display of temperature, humidity, carbon dioxide, formaldehyde, and other gases within feed storage tanks, as well as cooling and ventilation functions. It consists of a display module, a temperature and humidity detection module, a button module, an alarm module, a clock module, and cooling and ventilation modules. When measured data exceeds preset values, cooling and ventilation will commence, and an alarm will sound.
Project 8 : Wastewater Quality Monitoring System for Chemical Plants	This system enables the acquisition of environmental information such as temperature, humidity, and harmful gases at multiple points in the chicken house. It also records chicken house environmental data, laying hen feeding information, disinfection information, and other information into a traceability database, and produces QR code labels. Users can obtain detailed information about the egg production process by scanning the QR code.
	Water quality is monitored using turbidity sensors, pH sensors, and carbon dioxide sensors. The collected data is transmitted to the testing terminal via a wireless sensor network, stored in a database, and a monitoring platform is designed to display the test data.

These projects enable students to not only learn knowledge relevant to their course but also actively explore other related knowledge, broadening their horizons and expanding the breadth and depth of their knowledge. During project implementation, teachers should maintain an overall grasp of the project, communicate frequently with students, and guide them in analyzing difficulties and developing solutions. In this model, the teacher's role is more like that of a project leader, providing guidance, leading students into the project, helping them determine methods, and guiding their exploration. Throughout the project, students and teachers shift their original roles to become project leaders and members. Through project practice, both teachers and students change their original roles, facilitating smoother communication and enhancing students' exploratory and practical spirit.

Assessment methods and evaluation criteria: Course assessment includes regular assessment and final assessment, with a weighting of 3:7.

Regular assessment: Regular assessment focuses on process and periodic evaluation, with classroom performance and homework accounting for 4:6. Classroom performance is assessed through in-class quizzes by the teacher, and grades are given based on the test results. Homework is assigned after each (or several) learning units, with a time limit for completion, and grades are given based on the quality of completion. Students are required to take at least 5 self-tests after class.

Final exam: Based on the course objectives, a variety of questions will be designed to assess students' understanding of the five major components of computer hardware and the concepts and structures of buses. The exam will focus on students' mastery of relevant theoretical knowledge and their ability to solve related engineering problems. Each exam will have a corresponding grading standard designed based on the exam questions. The final exam will be closed-book, with the written exam score out of 100, weighted at 0.7 and included in the final overall grade, as shown in Table 3.

Table 3 Assessment and Evaluation Methods for Achieving Course Objectives and Comparison of Grades

Course Objectives	**Assessment Content**	**Assessment process**			
		Regular assessment / A (30%)A = a1 * 40% + a2 * 60%		**Final Exam/B (70%)**	**Grade ratio/A*30%+B*70%**
		Classroom grades/a1 (40%)	**Homework/a2(60%)**		
Target 1	Data representation and operation methods in computers, overflow principles and judgment methods, working principle of arithmetic unit, working principle of memory, word extension of memory, address mapping of main memory and cache, microprogram related concepts and control systems.	60	60	60	60
Target 2	Data format, instruction representation and addressing modes, memory working principle, locality principle, pipeline working principle, and the entire instruction cycle operation process from instruction fetching to instruction execution by the controller.	40	40	40	40

Experimental Class:

The experimental score consists of two parts: the experimental results and the experimental report.

Experiment results were verified on-site, and students were required to present their findings in response to various questions. All experiments included thought-provoking and in-depth inquiry-based questions, requiring students to carefully explore and discuss the results after class.

The experimental indicators are shown in Table 4:

The evaluation criteria for experimental grades consist of the standardization of experimental procedures, the correctness of results, and the group presentations in each experimental class. The scoring indicators for experimental grades include: (1) standardization of experimental procedures; (2) correctness of experimental results; and (3) correct answers to relevant questions during the presentations.

Table 4 Evaluation Criteria for Experimental Results

Score	Evaluation Indicators
90-100	All indicators at all levels met the standards.
80-89	Indicator (1) is not up to standard, while other indicators are up to standard.
70-79	Indicator (3) is not up to standard, while other indicators are up to standard.
60-69	Indicator (2) is not up to standard, while other indicators are up to standard.
Less than 60 points	Not meeting the above criteria

The evaluation index points for the experimental report are shown in Table 5:
The experimental report is evaluated based on indicators such as completeness, accuracy, and standardization. The evaluation criteria for the experimental report include: (1) the experimental report has a complete structure and meets the writing requirements; (2) the experimental results are complete; and (3) the summary is substantial. Among them, indicator (2) is the key indicator, and (1) and (3) are non-key indicators. The score is evaluated based on the above indicators.

Table 5 Evaluation Criteria for Experiment Reports

Score	Evaluation Indicators
90-100	All indicators at all levels met the standards.
80-89	Key indicators met the standards, but non-key indicators (1) failed to meet the standards.
70-79	Key indicators met the standards, but non-key indicators (3) did not meet the standards.
60-69	Both key and non-key indicators failed to meet the standards.
Less than 60 points	Not meeting the above criteria

Course assessment and evaluation methods: (1) Theoretical courses: The learning outcomes of the course are judged based on the achievement of the course objectives and whether the relevant ideas and methods in the course can be used to solve engineering practice problems.
Course assessments consist of regular assessments and a final assessment, with a weighting of 3:7.
Regular assessment: Regular assessment focuses on process and periodic evaluation, with classroom performance and homework accounting for 4:6. Classroom performance is assessed through in-class quizzes by the teacher, and grades are given based on the test results. Homework is assigned after each (or several) learning units, with a time limit for completion, and grades are given based on the quality of completion. Students are required to take at least 5 self-tests after class.
Final exam: Based on the course objectives, the exam will feature a variety of questions covering a wide range of topics. It will assess students' understanding of the five main components of computer hardware and the concepts and structures of buses, with a focus on their theoretical knowledge and ability to solve related engineering problems. Each exam will have a corresponding grading standard. The final exam will be closed-book, with the written exam score out of 100, weighted at 0.7 and included in the final overall grade.

4 RESEARCH FINDINGS

1. Academic Performance: Using data from 230 students in the 2022-2023 (2nd) semester of the Computer Science and Technology major (Class of 2021) as the data source, the achievement rate of course objectives was calculated. The summary results of the achievement rate calculation are shown in Table 6. As can be seen from the achievement rate calculation results shown in Table 6, all course objectives were successfully achieved.

Table 6 Calculation Results of Course Objective Achievement

		Course Objective 1	Course Objective 2	Course Objective 3
Achievement calculate	Full marks	61.4	21.2	17.4
	Average score	55.4	18.9	14.3
	Target achievement rate (%)	**90.2%**	89.2%	82.1%

Calculations show that the overall achievement rate of course objective 1 is 0.902, that of course objective 2 is 0.892, and that of course objective 3 is 0.937. If we use 1 as the evaluation benchmark, with 0.6 representing achievement , 0.8 representing good, and 0.9 representing excellent, the calculation results show that objective 1 is rated excellent, while objectives 2 and 3 are rated good.
2.Personal Gains: The biggest gain from the innovative projects was that some students' learning and development potential and abilities, as well as their interpersonal and communication skills, exceeded teachers' expectations, demonstrating high IQ and EQ. Initially, it was hoped that most students would participate in these innovative projects. However, it was found that students had different self-perceptions, abilities, and expectations, so only a small number of

students actively participated in the project development and persevered. It was precisely these students' efforts that yielded fruitful results. Several students in the project group were recommended for admission to prestigious graduate programs, and many others found their ideal jobs. Those recommended for admission not only had excellent academic records but also received bonuses due to awards won during project participation. Students admitted to graduate programs gained an advantage in interviews due to their practical project experience. Many students also gained knowledge and experience through project participation, leading to ideal jobs. Although only a small number of students persevered in the projects, this may significantly impact their future life trajectories and holds extraordinary significance for their families. At the same time, some projects are also characterized by continuous development, which inadvertently has a positive influence on students by passing on knowledge and skills and providing ongoing support.

5 CONCLUSION

The cultivation of "professional and innovative talents" is a systematic project that requires combining innovation with courses through improving teachers' professional skills, opening innovative practice sessions, sorting out course content, and improving teaching methods to enhance the effectiveness of course teaching and provide a platform for cultivating more "professional and innovative talents" who meet the needs of social and economic development [9,10].

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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