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Reflections on the Construction of Mechanical Engineering Course Clusters Inspired by the Reform and Innovation of the "Principles of Single-Chip Microcomputers and Interface Technology" Course

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Abstract

With the rapid development of the intelligent manufacturing industry, the traditional curriculum system for mechanical engineering majors struggles to meet the demand for cultivating talents capable of designing and implementing mechatronic systems. Taking the reform of the "Principles of Single-Chip Microcomputers and Interface Technology" course as an opportunity, this paper introduces Engestrom's third-generation activity theory as a theoretical framework to construct an activity system for mechanical engineering course clusters, with project cases serving as mediating tools. By carefully selecting seven core courses and five typical project cases, the initiative breaks down traditional course barriers and achieves an organic integration of knowledge consolidation and capability cultivation. Practical applications have demonstrated that this course cluster construction model can effectively enhance students' engineering practical abilities and systematic thinking capabilities, providing a feasible reform path for cultivating application-oriented undergraduate talents in mechanical engineering.

Keywords

Principles of Single-Chip Microcomputers and Interface Technology; Course Cluster Construction; Activity Theory; Project-Based Teaching; Mechanical Engineering

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1. Reform Opportunity

With the in-depth advancement of the "Made in China 2025" strategy and the rapid development of the intelligent manufacturing industry, industrial enterprises have set higher requirements for mechanical graduates' electromechanical control skills, particularly their practical and innovative application abilities in intelligent manufacturing systems based on single-chip microcomputers [1]. As a core course in the Mechanical Design, Manufacturing, and Automation major, the Principles and Interface Technology of Single-Chip Microcomputers serves as a crucial pillar for the transition from traditional machinery to intelligent manufacturing. The quality of its teaching directly relates to whether students can meet the demands of industry transformation and upgrading.

However, taking the Mechanical Design, Manufacturing, and Automation major at Geely University as an example, traditional teaching of single-chip microcomputer courses faces numerous issues: the course content lacks sufficient connection with prerequisite courses, leading to insufficient learning motivation among students; the teaching lacks guidance from authentic and advanced engineering project cases, resulting in inadequate practical application abilities among students; and the course design lacks avenues and platforms for fostering innovation, leaving students with weak engineering innovation capabilities [2]. Therefore, we have decided to undertake reform and innovation in the course "Principles and Interface Technology of Single-Chip Microcomputers."

2. Problem Awareness and Theoretical Guidance

2.1. Problem Awareness

During the reform process, we have recognized that reforming a single course is unlikely to fundamentally address the systemic issues related to student capability development. The current curriculum system in mechanical majors largely remains based on the "island model" of compartmentalized teaching [3]. Each course, as an independent "activity system," possesses its own set of rules (syllabus, assessment criteria), tools (textbooks, experimental equipment), community (instructors and students), and division of labor (roles of teachers and students). While this model facilitates the systematic transmission of knowledge, it contradicts the interdisciplinary and collaborative nature required to solve modern engineering problems [4].

The issues of students' insufficient learning motivation, inadequate practical abilities, and a lack of engineering innovation capabilities cannot be resolved solely through the reform of a single course. The root causes of these problems lie in the lack of effective integration among courses, fragmented knowledge transmission, and the difficulty in forming systematic competencies[5]. Therefore, we require a systematic solution capable of integrating resources from multiple courses.

2.2. Theoretical Guidance

Engeström's "Third-Generation Activity Theory" [6] provides us with theoretical guidance. The core analytical unit of this theory is the activity system, which comprises six interconnected core elements: subject, object, tools, rules, community, and division of labor. The central tenet of the theory is that the most effective learning occurs during the processes of "boundary crossing" and "collaborative construction" across multiple activity systems in response to complex challenges.

3. Construction of the Course Group Activity System

3.1. Course Selection

Based on the Third-Generation Activity Theory, we have selected seven core courses to construct the Course Group Activity System. These courses cover the complete process from "conceptual design" to "physical implementation" and then to "intelligent control[7]," reflecting the interdisciplinary integration of "mechanics-electronics-control.[8]"

3.2. Project Selection

Projects serve as the bridge connecting course knowledge with student capabilities and are the key mediating tool for activating the entire "Course Activity System." We have chosen five typical projects that collectively form a logically coherent and progressively structured project system. [9]

3.3. Decomposition of Practical Content

Each project is broken down into individual courses, ensuring that each course has clear, specific, and irreplaceable practical tasks. Below is an example of the breakdown of practical content for the Smart Inductive Desk Lamp project:

Table 1. Six Core Elements of the "Course Group Activity System"

Core Element	Theoretical Explanation	Course Group Application
Subject	The executor of the activity, the focus of analysis.	Teaching team for "Principles of Microcontrollers and Interface Technology".
Object	The target directly addressed by the activity; it is what is operated on, modified, or transformed.	Students' systematic ability to solve complex engineering problems.
Tools	The mediating artifacts used by the subject to act upon the object.	Shared comprehensive project cases.
Rules	The explicit or implicit norms, regulations, conventions, and standards within the activity system.	New practical teaching syllabus, cross-course assessment scheme.
Community	The multiple individuals and subgroups who share the same object.	Teachers and students from all courses participating in the reform.
Division of Labor	The horizontal division of tasks and vertical division of power and status within the community.	Specific task decomposition for each course within the project.

Table 2. Reasons for Course Selection and Role Distribution

Course Name	Role Description	Reason for Inclusion
Mechanical Drawing and Computer Graphics	The "language" of engineering and the foundation of design expression.	The realization of any mechanical product begins with the expression of design concepts, forming the basis for subsequent manufacturing, assembly, and inspection activities.
Computer-Aided Design (CAD)	The "digital twin" and virtual verification platform for products.	A core tool in modern engineering design, enabling digital design and virtual verification.
Fundamentals of Mechanical Design	The designer of the product's "skeleton and muscles".	Addresses fundamental questions of whether a product "can function and is safe," ensuring the reliability of mechanical structures.
Principles of Microcontrollers and Interface Technology	The "intelligent brain" and system integration hub of the product.	The core of "intelligent" mechanical systems, serving as the bridge connecting "mechanical" and "electrical" systems.
Sensors and Detection Technology	The "sensory system" of the product.	Provides "senses" for intelligent systems, converting physical signals into electrical signals.
Mechatronic Transmission Control	The "limbs" and power actuators of the product.	Solves the problem of "how to make the machine move," key to transforming control signals into mechanical motion.
Fundamentals of Control Engineering	The optimizer of system "behavior and performance".	

Table 3. Project Adaptability Analysis Table

Project Name	Coverage & Decomposability	Difficulty Progression	Engineering Practicality	Relevance to Core Courses	Feasibility & Safety	Engagement Factor
Smart Sensor Desk Lamp	Covers mechanical structure, sensing, control, and actuation.	Introductory Level: Simple structure, clear function, perfect as a starting point.	Reflects product design thinking, though with a weaker industrial context.	The microcontroller processes sensor signals and controls the LED, serving as the absolute core.	Low cost, no moving parts, very safe.	Closely related to daily life, easy to understand and engaging.
Smart Waste Sorting Bin	Builds on the lamp by adding an actuator (servo/motor).	Intermediate Level: Introduces motion control, increasing complexity.	Addresses current environmental topics, with a clear functional goal.	Logic control is more complex, highlighting the microcontroller's decision-making role.	Slow movement, low force, high safety.	Strong social relevance, can inspire a sense of purpose in students.
Miniature Pneumatic Sorting Line	Perfectly covers mechanics, pneumatics, sensing, control, and system integration.	Comprehensive Level: Simulates industrial automation, high complexity, requires teamwork.	Represents a micro industrial site, with very strong engineering practicality.	Involves complex sequential control with multiple sensors and actuators; a classic microcontroller application.	Requires an air source, but pressure is low; safe with standard operation.	A tangible representation of Industry 4.0 and automation, highly attractive.
5-DOF Teaching Manipulator	Focuses on kinematics, structure, and precision control.	Challenging Level: Involves robotics concepts, represents the peak of knowledge application.	Represents advanced robotics technology, with cutting-edge practicality.	Multi-channel PWM coordinated control is an advanced application of microcontroller technology.	Complex structure requires precise assembly, but moving parts pose manageable risk.	The robotics theme has a natural, strong appeal to students.
Smart Material Handling Cart	A mobile robot system, covers all course areas, highest level of integration.	Final Challenge Level: Dynamic platform requiring integrated solutions for navigation, grasping, scheduling, etc.	Represents advanced fields like AGV/AMR; a complete system-level project.	As the system's "brain," the microcontroller handles all perception, decision-making, and motion control.	Involves a mobile base; requires attention to battery safety and movement space management.	Combines autonomous driving and robotics; the ultimate engagement point.

Table 4. Example of Breakdown of Practical Content for the Smart Inductive Desk Lamp Project

Course Name	Practical Content Breakdown
Mechanical Drawing and Computer Graphics	Create 2D part drawings for lamp components such as the bracket, lampshade, and base. Learn the drawing representation and dimensioning of sheet metal or plastic parts.
Computer-Aided Design (CAD)	Create a 3D model of the desk lamp, perform virtual assembly and interference checks, and conduct motion simulation of the lamp arm joint to verify its adjustment range.
Fundamentals of Mechanical Design	Design the hinge mechanism for the lamp arm, perform torque calculations and stability analysis, and select appropriate standard components such as pivot shafts.
Principles of Microcontrollers and Interface Technology	Learn to read signals from PIR (Passive Infrared) sensors and photoresistors; program PWM (Pulse Width Modulation) output to control RGB-LED for dimming and color adjustment.
Sensors and Detection Technology	Gain in-depth knowledge of the principles, characteristics, and application circuits for PIR sensors, photoresistors, and touch sensors.
Mechatronic Transmission Control	Learn the principles of LED driver circuits, such as constant current drivers.
Fundamentals of Control Engineering	Establish a system block diagram for closed-loop brightness control, introducing the concepts of open-loop and simple closed-loop control.

4. Implementation Results and Conclusions

After a semester of pilot implementation, the construction of the course cluster has achieved initial success. Students' enthusiasm for learning has significantly increased, and they are now able to actively integrate knowledge from multiple courses to solve complex engineering problems. The project-driven learning model has enabled students to gain a deeper understanding of knowledge points and significantly improved their practical abilities.

This paper takes the curriculum reform of "Principles and Interface Technologies of Single-Chip Microcomputers" as a starting point and constructs an activity system for mechanical professional course clusters using third-generation activity theory. By carefully selecting courses and project cases, it organically integrates knowledge points from multiple courses into project practices, breaking down the barriers of traditional subject-based teaching. This model not only enhances students' interest in learning and practical abilities but also provides a reference path for the construction of course clusters in application-oriented undergraduate institutions.

In the future, we will further refine the evaluation system for course clusters, expand the reach of our reform achievements, and explore more project cases suitable for course cluster teaching, continuously optimizing the operational mechanism of the course cluster activity system.

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Disclosure statement

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References

[1] Liu P, 2025, Development Trends of Mechanical Design, Manufacturing, and Its Automation Technology in the Context of Intelligent Manufacturing. Auto Time, (20): 123-125.

[2] Chao C, Yuan W, Lin T, 2025, Three-tier progressive teaching innovation and practice of the course "Principles and Interface Technology of Microcontrollers" from the perspective of emerging engineering. Journal of Education and Educational Policy Studies, (3): 69-73.

[3] Liu H, Gong S, Cao L, 2025, Research on the Construction of Mechanical Professional Course Groups in the Context of Emerging Engineering. Education and Teaching Forum, (34): 45-48.

[4] Liu Y, Shi Y, Hao R, 2025, Construction and Practice of Course Groups Guided by the OBE Educational Philosophy in the Context of Emerging Engineering: Taking the Signal Analysis and Processing Course Group as an Example. Technology Wind, (22): 28-30.

[5] Yuan J, Fang H, Xiao H, 2024, Research on the Construction of Teaching Teams for Core Course Groups in Mechanical Specialties in the Context of Emerging Engineering. Education and Teaching Forum, (01): 78-81.

[6] Yu L, 2012, Engestrom's Activity Theory. Northern Literature (Second Half of the Month), (01): 224.

[7] Yang S, 2021, Research on the Construction of Mechanical Professional Course Groups in the Context of Emerging Engineering. Gansu Science and Technology, 37(19): 73-74+134.

[8] Chen N, Lu M, Zhang H, 2025, Exploration of a Project-Centered Teaching Model for the Microcontroller Course. Computer Education, (07): 238-243.

[9] Si G, Wang Y, 2025, Application of Microcontroller Development Projects in the Teaching of "Sensors and Detection Technology": Taking Photoelectric Sensors as an Example. Technology Wind, (25): 114-116+162.

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