

Exploration and Practice of Generative-AI-Empowered Teaching for Systems Engineering Course

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Abstract: The systems engineering course features both theoretical and practical properties. Its methodological attributes lead to abstract teaching content and difficulties in student comprehension. Traditional teaching modes can hardly effectively cultivate students' systems-thinking ability and competence to solve complex problems. The rapid development of generative AI technology provides brand-new paths for the teaching reform of systems engineering courses. Based on the disciplinary characteristics of the systems engineering course — “holism, relevance and dynamics”, combined with the technical strengths of generative AI in knowledge generation, scheme deduction and model construction, this paper puts forward a trinity teaching mode of “AI-assisted autonomous study — classroom collaborative inquiry — system scheme verification”. Under this mode, teachers design systematic learning outlines, students complete system-analysis tasks with the help of generative AI, and multi-scheme comparison and critical verification are carried out in class, so as to realize the coordinated development of systems-engineering thinking and AI-application capabilities. Taking the teaching unit of “system evaluation methods” as an example, this paper illustrates the implementation path of this mode. Research shows that this mode helps stimulate students' learning initiative, improve their systems-thinking ability and human-AI collaboration literacy, and provides references for the teaching reform of engineering-oriented courses in the generative AI era.

Keywords: Generative artificial intelligence; Systems engineering; Teaching mode; Systems thinking; Human-AI collaboration

Online publication: October 26, 2026

1. Introduction

Systems engineering is an engineering technology that studies the organization, management and operation of systems. Its core lies in adopting systems thinking and methodologies to analyze and resolve complex engineering and management problems. As a core course for majors in management science and engineering, systems engineering aims to cultivate students' ability to analyze and solve problems from a holistic and

comprehensive perspective.

The rapid development of generative AI offers new technical paths to break through the above-mentioned teaching dilemmas. Studies indicate that embedding generative AI into engineering-course design and teaching practice can effectively enhance the forward-looking nature and adaptability of courses, and deliver more efficient and diversified learning experiences for students ^[1]. Other studies point out that the internal mechanism of generative-AI-empowered college classroom-teaching reform is reflected in multi-dimensional coupling of objectives, structures and processes. That is, through consistent alignment at the objective level, collaborative reorganization at the structural level, and closed-loop embedding at the procedural level, classroom-teaching modes are promoted to transform from one-way transmission to intelligent collaboration ^[2]. In the field of engineering education, an AI-driven multi-agent training paradigm for engineering-thinking competence has been put into practice in multiple universities. Via task-driving, role-playing and dynamic-scenario generation, it systematically integrates training paths for key capabilities including systems thinking, metacognitive thinking and problem-construction thinking ^[3].

Given the above background, based on the disciplinary features and teaching pain points of the systems engineering course, this paper explores concrete paths and implementation strategies for generative-AI-empowered systems-engineering-course teaching, so as to provide references for the teaching reform of engineering-oriented courses under the background of Emerging Engineering Education.

2. Disciplinary characteristics and teaching dilemmas of the systems engineering course

2.1. Disciplinary characteristics of the systems engineering course

What distinguishes the systems engineering course from general engineering courses lies first and foremost in its problem-solving perspective. Students are required not only to master specific analytical methods, but also to understand complex systems from holistic, correlative and evolutionary perspectives. From a holistic perspective, improvement of local performance does not necessarily bring enhancement of overall system effects. Therefore, when analyzing problems, it is essential to define system boundaries and coordinate all components as well as their joint effects. From a correlative perspective, it is necessary to sort out causal relationships, feedback processes and time delays among elements, and identify key factors that truly affect system operation. From an evolutionary perspective, attention should not merely be paid to states at a single time point; it is also required to judge system development trends and long-term impacts brought by different intervention measures.

Accordingly, systems-engineering teaching should not be confined to lecturing on concepts and methods. More importantly, it shall help students form corresponding thinking habits: when confronted with complex problems, they can proactively define boundaries, analyze relationships, compare schemes, and adjust judgments in a timely manner according to practical outcomes. Such competence cannot be acquired through one-way lecturing; it needs to be gradually developed amid students' continuous analysis, decision-making, feedback and revision.

2.2. Main dilemmas of traditional teaching modes

From the perspective of teaching practice, the systems engineering course mainly has three problems. First, teaching content overemphasizes theoretical lecturing while practical sessions are relatively weak. Second,

teaching methods are relatively monotonous and students lack sufficient active participation. Third, there are no stable and effective practical carriers for cultivating systems thinking. Meanwhile, when students use intelligent tools for learning assistance, they often fail to raise accurate questions, and tend to directly accept generated outputs without necessary data checking, logical analysis and result verification. Existing research shows that the progressive “guidance-inquiry-reflection” teaching approach can improve students’ problem-construction competence, critical thinking and metacognitive proficiency ^[4], which can serve as the theoretical foundation for the teaching-mode design in this paper.

2.3. Application value of generative AI in systems-engineering teaching

Applying generative AI to systems-engineering teaching can, to a certain extent, make up for the deficiencies of traditional classrooms in knowledge preparation, scheme comparison and practical training. At the pre-class learning stage, students can leverage relevant tools to organize concepts, methods and case materials, build preliminary understanding of systems-engineering methodologies, and get prepared for discussions and task practice in flipped classrooms ^[5]. In classroom teaching, teachers can guide students to compare different schemes together with their applicable conditions, analyze hypotheses, constraints and potential impacts behind schemes to make decision-making processes more concrete. For contents such as system modeling and system dynamics, generated data or simulated scenarios can also be adopted for low-cost practice.

3. Mode design for generative-AI-empowered systems-engineering teaching

Based on the disciplinary characteristics of the systems engineering course and technical strengths of generative AI, this paper constructs a trinity teaching mode of “AI-assisted autonomous study — classroom collaborative inquiry — system scheme verification”.

3.1. Pre-class: AI-assisted autonomous study of system knowledge

At the pre-class stage, teachers select concrete cases such as regional water-resource allocation, and design progressive question chains in accordance with basic system-analysis workflows to guide students to complete system-boundary definition, identification of element relationships, model-structure design, parameter estimation and result verification in sequence. Focusing on these questions, students consult textbooks, case materials and relevant literature, and understand basic principles and operating procedures of interpretive structural modeling, system-dynamics flow diagrams, analytic hierarchy process, entropy-weight method and system-reliability-analysis models. When necessary, intelligent tools can be used to sort out concepts, compare methods, or inspect analytical ideas, yet relevant content still needs to be cross-checked against textbooks and literature. Through this process, students form relatively complete knowledge frameworks before class and get prepared for subsequent modeling, discussions and scheme design ^[6].

3.2. In-class: Collaborative inquiry and scheme deduction based on real-world problems

Classroom teaching focuses on complete system-analysis tasks. Focusing on comprehensive-application objectives of the course, teachers design complex tasks covering system modeling, system evaluation and reliability analysis, for instance, optimization of urban public-transportation systems, evaluation and reliability demonstration of regional water-resource-allocation schemes. Divided into groups of 4-5 members, students finish system definition, boundary determination, subsystem division, element-relationship analysis,

alternative-scheme design, comprehensive evaluation and reliability analysis within specified class hours.

In the course of task implementation, teachers are mainly responsible for raising key questions, observing group progress and offering targeted guidance. When students encounter problems such as ambiguous system boundaries, confusing analytical levels, unreasonable indicator setting or insufficient demonstration basis, teachers organize timely discussions to help them sort out system relationships, revise analytical ideas and improve demonstration processes ^[7].

3.3. Post-class: Multi-dimensional critical verification of system schemes

Different from ordinary courses, feedback in systems-engineering teaching shall highlight systematicness, namely examining students' analytical schemes from multi-dimensional perspectives. This mode sets up the link of "scheme comparison and verification". Teachers select different schemes produced by each group before or in class, organize public comparison and group discussions, with emphasis on inspecting system boundaries, element relationships, indicator setting and demonstration basis ^[8]. Studies show that teaching reform is not a simple superposition of technical tools, but the joint effect of teaching subjects, activity procedures, learning environments, and educational objectives. Its key lies in improving teaching support according to individual student differences ^[9].

4. Implementation path combined with the teaching unit of "system evaluation methods"

4.1. Pre-class: Targeted autonomous learning centered on problems

Before class, teachers sort out learning outlines around "system evaluation methods", dividing contents into three parts: first, basic concepts including evaluation-indicator systems, weights and comprehensive evaluation values; second, commonly-adopted methods such as analytic hierarchy process, entropy-weight method and fuzzy comprehensive-evaluation method; third, applicable scenarios and application cases for different evaluation methods. On this basis, teachers set several interrelated questions to guide students to carry out purposeful pre-class learning.

According to the outlines, students learn principles, procedures and applicable conditions of various evaluation methods and search for relevant cases with the help of generative AI. For controversial content such as indicator selection and weight determination, students shall state information sources and record confusing points for further in-class discussion.

4.2. In-class: Deepened understanding through scheme comparison

In class, students finish system-evaluation tasks in groups, such as service-level evaluation of urban public-transportation systems, evaluation of enterprises' technological-innovation capacity, or evaluation of regional ecological-environment quality. After drawing tasks, combined with pre-class knowledge, each group completes system-boundary definition, construction of evaluation-indicator systems, selection of evaluation methods and design of implementation workflows. During scheme design, students may use generative AI to supplement alternative indicators, compare different evaluation methods, or check the consistency of judgment matrices for the analytic hierarchy process.

The final 30 minutes of class are reserved for scheme presentations and inter-group questioning. Other groups mainly put forward opinions from perspectives including whether system boundaries are clear, whether

indicator selection is comprehensive, whether method selection is appropriate and whether data sources are reliable ^[10]. Based on discussions, teachers supplement explanations for common problems and help students understand applicable conditions and limitations of different methods.

4.3. Post-class: Inspection and revision of generated schemes

After class, teachers select representative generated content from each group's schemes, such as evaluation indicators, weight settings, and comprehensive-evaluation results, and organize students for further verification. Students first trace sources of indicators and parameters and judge whether they conform to evaluation objectives and system boundaries. Next, they inspect indicators for repetition, omission or logical contradictions. On this basis, weights and evaluation results are recalculated through expert judgment, sensitivity analysis and multi-scenario comparison. After finishing inspection, combined with course theories and consulted literature, students make judgments on whether to retain, revise or reject original schemes and submit brief revision notes ^[11]. Human-AI collaborative design teaching integrated with reflection strategies can effectively foster learners' critical-thinking development. When using AI, students need to learn to judge when to accept, modify or reject AI-generated outputs ^[12].

5. Conclusion

The priority of systems-engineering-course reform does not lie in increasing the frequency of technical-tool application, but in cultivating students' competence to understand problems, analyze relationships and work out feasible solutions from a holistic perspective. Combined with course characteristics and practical teaching difficulties, this paper constructs the teaching mode of "pre-class autonomous study — classroom collaborative inquiry — post-class scheme verification". Pre-class learning helps students acquire necessary knowledge preparation; classroom teaching takes real-world problems as carriers and promotes students to deepen understanding via discussions, modeling and scheme comparison; post-class sessions cultivate students' awareness of prudent judgment and continuous improvement through data verification, logical inspection, result recalculation and reflective revision. These three links are closely connected, forming a complete process integrating knowledge acquisition, method application and competence cultivation.

In practical implementation, intelligent tools shall always serve teaching objectives and must not replace students' independent thinking or teachers' professional judgment. Teachers need to guide students to pay attention to the basis, applicable conditions, and potential biases of generated content, treating it as a resource for auxiliary analysis and idea inspiration instead of standard answers to be directly accepted ^[13]. The mode proposed in this paper still needs further verification in teaching practice. Follow-up comparative research can be carried out targeting different contents such as system modeling & simulation and system dynamics, to investigate its actual influences on systems thinking, collaboration capabilities and complex-problem-solving competence, and continuously optimize teaching design according to implementation outcomes ^[14].

Disclosure statement

The author declares no conflict of interest.

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