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Construction and Practice of "Three Stage-Five Link" Blended Teaching Model in Engineering Drawing Empowered by AI Empowered

Yuanyuan Cui[1,a,*]

[1]*School of Mechanical Engineering, University of Shanghai for Science and Technology, Shanghai, 200093, China*
[a]*yyhdlg@163.com*
[*]*Corresponding author*

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Abstract: Engineering Drawing is a fundamental core course for engineering majors. Traditional teaching methods face challenges such as the difficulty in cultivating spatial thinking, delayed feedback on drawing standards, and the inability to address individual student differences. This paper proposes a blended teaching reform model framed as "AI-empowered-Three stage-Five link", integrating technologies like Large Language Models (LLMs), AI image recognition, and intelligent agent evaluation into the entire teaching process. By constructing AI-assisted knowledge graphs, facilitating collaborative classroom inquiry, and implementing automated drawing evaluation via AI agents, the model reconstructs a classroom ecosystem that balances "teacher guidance" with "student centrality". Practice demonstrates that this model effectively enhances the spatial imagination, awareness of drafting standards, and engineering expression capabilities of students, while simultaneously reducing the grading burden on teachers. It provides a scalable, lightweight pathway for the digital transformation of Engineering Drawing courses in general colleges and universities.

1. Introduction

As the foundational course serving as the "language of engineering" for majors in mechanical, civil, architectural, and electrical engineering, Engineering Drawing course bears the core responsibility of cultivating the spatial thinking, projection representation, and engineering standard literacy of students [1,2]. However, traditional instruction has long been plagued by the following challenges: (1) The cultivation of spatial imagination relies heavily on the experience and physical models of instructors, resulting in monotonous teaching methods; (2) The heavy workload of grading drawing assignments, such as three-view drawings, sectional views, and assembly drawings, makes it difficult for teachers to provide personalized feedback for each student; (3) With the numerous clauses of the National Standards on Technical Drawings (GB/T), students often struggle to bridge the gap between memorization and practical application; (4) Significant disparities in student

backgrounds render the “one-size-fits-all” approach inadequate for meeting differentiated learning needs [3,4].

In recent years, Large Language Models (LLMs) represented by ChatGPT and DeepSeek, along with multimodal AI technologies, have developed rapidly. These advancements provide new tools for course instruction, including automatic generation of knowledge graphs, intelligent question answering, image recognition for grading, and digital human explanations [5]. However, systematic research on AI-empowered Engineering Drawing instruction remains in its early stages, with most practices still limited to the superficial application of "using AI for drawing."

Based on the characteristics of the Engineering Drawing course, this paper constructs a blended teaching reform model of “AI-Empowered Three-Stage Five-Link”. This model embeds AI technology into three phases: pre-class preview, in-class collaboration, and post-class consolidation, while covering three dimensions of knowledge construction, skill training, and literacy cultivation. The aim is to provide an operable and scalable practical solution for the intelligent transformation of foundational engineering courses.

2. Overall Design of the Teaching Reform Model

2.1 Teaching Process of the Three stage-Five link Model

The teaching reform model adopts the “Three Stage-Five link” framework and divides the instruction of the Engineering Drawing course into three stages and five core links. The three stages are pre-class autonomous preview, in-class collaborative inquiry, and post-class consolidation and improvement. The five-core links run through the entire process of knowledge construction, skill training, and literacy cultivation, forming a coherent and closed-loop teaching process.

2.2 Stage One: Pre-class Autonomous Preview

The pre-class stage focuses on knowledge guidance and diagnosis of learning conditions, including the following two links.

The pre-class stage focuses on knowledge guidance and diagnosis of learning conditions. In the first link, knowledge graph-guided learning, AI is used to automatically generate mind maps, preview micro-lectures, and test question banks. These resources help students organize the knowledge system of Engineering Drawing, clarify learning objectives, and complete pre-class knowledge construction.

In the second link, student profiling and precise recommendation, AI generates individual learning profiles based on pre-class test results, identifies knowledge weaknesses and learning differences, and recommends differentiated learning resources, thereby providing a basis for layered classroom instruction.

2.3 Stage Two: In-class Collaborative Inquiry

The in-class stage focuses on interactive teaching and practical training. The third link, interactive classroom teaching, uses AI to support projection demonstration, real-time error correction, and the design of group collaboration tasks, enhancing classroom interaction and guiding students to conduct collaborative inquiry on projection rules, view representation, and drawing standards.

The fourth link, practical operation and immediate feedback, employs AI image recognition to evaluate the standardization of student drawings and applies AI-based analysis to CAD operation screen recordings. Problems can thus be identified promptly, and targeted feedback can be provided to improve engineering expression ability.

2.4 Stage Three: Post-class Consolidation and Improvement

The post-class stage emphasizes evaluation, feedback, and ability expansion. The fifth link, intelligent evaluation and expansion, relies on AI agents to complete drawing assessment, generate personalized improvement suggestions, and guide students to deepen their understanding through extended engineering cases, thereby extending learning from knowledge mastery to the improvement of engineering literacy.

Through the organic connection of these three stages and five core links, the model achieves full-process integration of pre-class preview and diagnosis, in-class collaborative inquiry, and post-class evaluation and expansion. It promotes the transformation of Engineering Drawing instruction from one-way lecturing toward intelligent assistance, precise feedback, and personalized learning.

3. Pre-class Autonomous Learning: AI-Driven Knowledge Construction and Precise Guidance

3.1 AI-Assisted Construction of Knowledge Graphs

The knowledge points in the Engineering Drawing course are highly fragmented, covering multiple modules such as descriptive geometry, projection principles, methods of component representation, standard and commonly used parts, part drawings, and assembly drawings. Instructors can upload the course syllabus to large language models such as DeepSeek, Chat GPT and other automatically generate structured knowledge graphs through prompt engineering. As a typical example, an instructor may input the prompt: “Extract all core concepts from Chapter 5, ‘Methods of Component Representation,’ including basic views, directional views, partial views, oblique views, sectional views, and cross-sectional views, and output a hierarchical diagram in Mermaid syntax”. The Mermaid code generated by AI can then be imported into drawing tools such as draw.io or embedded into the course website to produce an interactive mind map for students to browse independently before class. In addition, instructors may further prompt AI to “design ten preview multiple-choice questions and three true-or-false questions based on the content of Chapter 5”, thereby completing the construction of a pre-class question bank.

3.2 Student Profiling and Precise Recommendation

Before class, students complete pre-class tests through an AI-generated online quiz platform. Based on their responses, the system automatically generates student profiles and classifies learners into categories such as “weak spatial thinking”, “insufficient mastery of standards”, and “generally competent”, after which differentiated learning resources are recommended. Specifically, for students with weak spatial thinking, the system provides AI-generated three-dimensional rotation animations and step-by-step projection decomposition videos; for students with insufficient mastery of standards, it provides AI-organized comparison tables of GB/T drawing standards and mnemonic cards; and for generally competent students, it offers extended engineering cases, such as the interpretation of an assembly drawing of a certain type of speed reducer. In this way, precise guidance based on diagnostic assessment of learning conditions is achieved.

3.3 AI Digital Human Micro-Lecture Explanation

AI tools are employed to generate digital human avatars for explaining difficult content in Engineering Drawing. For example, an instructor may input the prompt: “Prepare an explanatory script for ‘the projection rules of three-view drawings-length alignment, height levelness, and width equality,’ accompanied by the unfolding process of the three projection planes of a simple rectangular

prism, and generate a three-minute digital human lecture video". The resulting micro-lecture can be viewed repeatedly by students before class, helping to reduce the cognitive load of in-class instruction and improving the effectiveness of autonomous learning.

4. Pre-class Autonomous Learning: AI-Driven Knowledge Construction and Precise Guidance

4.1 AI-Assisted Interactive Projection Teaching

The collaborative classroom learning stage relies on an AI-supported collaborative learning platform and interactive technologies to construct a classroom ecology characterized by teacher guidance and student-centred participation. In the teaching of "three-view drawings of composite solids", instructors can use AI-generated webpages containing three-dimensional models. Students are able to freely rotate and section the models and complete online drawing of three-view drawings on the webpage. The system compares student outputs with standard answers in real time and marks the correctness of projection relationships in red or green, thereby achieving step-by-step immediate feedback and reinforcing students' understanding of projection rules.

4.2 Design of Exploratory Collaborative Tasks

For comprehensive and exploratory content in Engineering Drawing, large language models provide convenient support for instructors in designing discussion questions and student exploration themes. In a flipped classroom activity on "selection of sectional views", students work in groups to propose different sectioning schemes for the same component, such as a bearing housing. They then compare the expressive effects of these schemes using AI-generated three-dimensional sectioning animations, discuss the optimal scheme, and justify their choices. In a group competition on "correction of drawing standard errors", AI automatically generates engineering drawings containing several GB/T errors, including incorrect line types, omitted dimensioning, and incorrect hatching directions. Each group identifies the errors within a time limit to strengthen their awareness of drawing standards. In a thematic debate on "from part to assembly", students discuss which expression scheme should be adopted for the assembly drawing of a speed reducer, while AI records the key points raised by each group in real time to support subsequent evaluation.

4.3 AI-Assisted Classroom Process Recording and Analysis

Through AI processing of classroom audio recordings, the system can automatically extract the number of participants, identify discussion viewpoints, organize the logical flow of discussion, and generate classroom discussion summaries. Instructors can use these records to evaluate the level of participation and the depth of thinking demonstrated by each group, thereby providing an objective basis for process-oriented assessment and improving the comprehensiveness and operability of classroom evaluation.

4.4 Immediate Student Feedback Mechanism

During practical activities such as "drawing interpretation", students obtain typical engineering drawing cases through AI-generated webpages and search for key information as required by the instructor, including surface roughness annotations, the meaning of geometric tolerances, and welding symbols. Students then capture screenshots of their results and post them to the course WeChat group or the teaching platform as immediate feedback on teaching effectiveness. Instructors can adjust subsequent teaching priorities based on this feedback, enabling dynamic optimization of

classroom instruction.

5. Post-class Consolidation and Evaluation: AI Agent-Assisted Grading and Personalized Feedback

5.1 AI Agent-Based Drawing Evaluation

Grading engineering drawing assignments, including hand-drawn and CAD drawings, is one of the most time-consuming tasks for instructors. This teaching reform introduces an AI agent-assisted grading mechanism to reduce the grading burden and improve evaluation consistency. The implementation process is as follows. First, students upload their completed drawings, including scanned copies or PDF files exported from CAD, to the teaching platform. The AI image recognition module then conducts a preliminary analysis to examine whether the drawing frame and title block are complete and standardized, whether line types such as thick solid lines, thin solid lines, dashed lines, and chain lines are correctly applied, whether dimensions are complete, clear, and compliant with GB/T standards, whether the direction and spacing of hatching lines in sectional views are standardized, and whether the selected views are reasonable and the projection relationships are correct. Based on these analyses, the AI agent generates a preliminary score and written feedback according to predefined grading criteria. For example, the instructor may input the prompt: “Based on the following grading criteria (drawing standardization 30%, projection correctness 40%, completeness of dimensioning 20%, and drawing neatness 10%), score this ‘bracket part drawing’ and point out deficiencies and improvement suggestions item by item”. Finally, the instructor conducts a random review of the AI-generated scores, with a sampling rate of no less than 20%, to ensure fairness and accuracy. The final grade is determined by the instructor.

5.2 Generation of Personalized Learning Suggestions

The AI agent automatically generates periodic learning reports based on students’ assignment scores across multiple submissions, identifies areas of weakness, and recommends targeted practice. For instance, the system may generate feedback such as: “In the last three assignments, this student showed a high error rate (60%) in the direction of hatching lines in sectional views. It is recommended to review the relevant provisions of GB/T 4457.4 and complete additional exercises 12 to 15”. By continuously tracking student performance, the AI agent can provide differentiated improvement suggestions, thereby supporting more precise and personalized post-class learning.

5.3 Recommendation of Extended Engineering Cases

After class, the AI system recommends extended engineering cases based on students’ classroom performance and assignment completion. Examples include complete interpretation of part drawings for a certain type of gear pump and drawing specifications for detailed architectural joint diagrams. This mechanism helps bridge the gap between classroom knowledge and engineering practice, guiding students to deepen their understanding of drawing standards and representation methods within authentic engineering contexts and thereby enhancing their engineering literacy.

6. Analysis of Teaching Reform Implementation Effects

6.1 Comparison of Student Achievement

To examine the effectiveness of the AI-enabled blended teaching reform, this study selected first-

year mechanical engineering students at a university as research participants and conducted a comparative experiment using parallel classes with similar teaching schedules, instructors, and student backgrounds. The experimental class adopted the AI-enabled blended teaching model and included 86 students, while the control class followed the traditional teaching model and included 82 students. The comparison of final examination results and related indicators between the two classes is presented in Table 1.

Table 1 Comparison of Achievement and Evaluation Indicators between the Experimental and Control Classes.

Indicator	Experimental Class	Control Class	Significance of Difference
Mean final examination score	78.4	72.1	$p<0.05$
Drawing standardization score rate	85.2%	73.6%	$p<0.01$
Spatial imagination test score	81.7	74.3	$p<0.05$
Course satisfaction (5-point scale)	4.52	3.87	$p<0.01$

As shown in Table 1, the mean final examination score of the experimental class was 78.4, which was higher than that of the control class (72.1), and the difference was statistically significant ($p<0.05$). In terms of the drawing standardization score rate, the experimental class achieved 85.2%, significantly higher than the 73.6% of the control class ($p<0.01$). This suggests that AI agent-assisted grading and immediate feedback help students master drawing standards more accurately. In the spatial imagination test, the experimental class obtained an average score of 81.7, higher than the control class score of 74.3 ($p<0.05$), indicating that AI-supported three-dimensional model interaction and real-time error correction contribute to the improvement of students' spatial thinking ability. Regarding course satisfaction, the experimental class reported a mean rating of 4.52, significantly higher than the control class rating of 3.87 ($p<0.01$), reflecting students' strong acceptance of the AI-enabled blended teaching model.

Overall, the experimental class outperformed the control class in academic achievement, mastery of drawing standards, spatial imagination ability, and course satisfaction. These results indicate that the "Three-Stage Five-Link" AI-enabled teaching model can effectively improve the teaching quality and learning outcomes of the Engineering Drawing course.

6.2 Changes in the Workload of Teachers

AI agent-assisted grading significantly reduced the workload of teachers in assignment evaluation. After the implementation of the teaching reform, the average time required to grade a single drawing decreased from 12 minutes to 3 minutes, including review time, representing an approximately 65% reduction in the overall grading workload. This reduction enabled teachers to devote more time to instructional design, classroom interaction, and personalized guidance, thereby improving the effectiveness and focus of their teaching efforts.

6.3 Student Feedback

The questionnaire survey showed that students generally responded positively to the AI-enabled teaching components. Specifically, 92% of students believed that the knowledge graphs generated by AI "helped establish a knowledge framework", 87% considered the immediate feedback provided by AI "effective in correcting drawing errors in a timely manner", and 78% indicated that they were "willing to rewatch difficult content" in digital human micro-lectures. These findings suggest that knowledge guidance, immediate feedback, and micro-lecture resources supported by AI are well accepted and contribute to the autonomous learning of students.

7. Conclusion

This study takes the Engineering Drawing course as a carrier and constructs an “AI-enabled, Three-Stage Five-Link” blended teaching reform model. Large language models, AI image recognition, and AI agent-based evaluation are systematically integrated into the entire teaching process, including pre-class, in-class, and post-class stages. The model forms a relatively complete instructional cycle through AI-assisted construction of knowledge graphs, student profiling and precise learning guidance, AI digital human micro-lectures, design of collaborative classroom tasks, AI-assisted recording and analysis of classroom processes, and AI agent-based drawing evaluation with personalized feedback.

The implementation results show that this model can effectively improve the teaching quality of the Engineering Drawing course and enhance the learning experience of students. The experimental class outperformed the control class in final examination scores, mastery of drawing standards, spatial imagination ability, and course satisfaction. At the same time, AI agent-assisted grading significantly reduced the time required to evaluate each drawing, decreasing the overall grading workload of teachers by approximately 65%. This reduction enabled teachers to devote more effort to instructional design and personalized guidance. With further development of multimodal AI technologies and intelligent CAD-based grading tools, AI-enabled applications in Engineering Drawing courses are expected to evolve toward more advanced forms of adaptive learning and engineering practice simulation.

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