Research on the Reform of the “Civil Engineering Drawing” Course in the Context of Artificial Intelligence

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Abstract: With the rapid advancement of artificial intelligence (AI), civil engineering drawing education faces dual challenges: the transformation of teaching models and evolving industry demands. This study examines persistent issues in the teaching of “Civil Engineering Drawing” courses—such as difficulties in developing spatial imagination, limited practical resources, and overly simplistic assessment methods—within the context of AI integration. A reform framework centered on “AI empowerment, virtual–real integration, and multidimensional reconstruction” is proposed. By incorporating intelligent software tools including CAD, BIM-Revit, and Blender, along with knowledge graph technology via the Learning Terminal platform, a comprehensive smart teaching system spanning “theory–practice–assessment” has been developed. Key initiatives include the introduction of 3D modeling software to facilitate spatial understanding, the design of dual-track experiments combining virtual simulation and hands-on operation to strengthen practical skills, and the implementation of a multidimensional evaluation system to assess student competencies comprehensively. Empirical evidence indicates that these reforms significantly enhance students’ spatial imagination, design capabilities, and human–machine collaboration skills, thereby effectively supporting the cultivation of civil engineering talent suited to the demands of intelligent construction.

Keywords: Civil Engineering Drawing; Artificial Intelligence; Virtual-Real Integrated Teaching; Teaching Reform; Knowledge Graph

1. Research Background

The rapid advancement of artificial intelligence (AI) has led to its widespread integration across various sectors, profoundly transforming traditional industries—including civil engineering. The emergence and implementation of smart construction concepts have also elevated the requirements for civil engineering education. It is no longer sufficient for professionals to possess only solid theoretical knowledge; they must also demonstrate robust innovative and practical skills, along with the ability to collaborate effectively with AI systems [1].

As a fundamental core course in civil engineering, “Civil Engineering Drawing” is generally introduced in the first year of undergraduate studies. It bridges secondary school geometry and three-dimensional architectural representation, playing an essential role in cultivating students’ spatial imagination, engineering design competence, and technical drafting proficiency. Mastery of the course has a direct impact on academic performance in follow-on specialized subjects and long-term professional growth.

However, the rapid advancement of artificial intelligence (AI) poses dual challenges for civil engineering drawing education: the transformation of traditional teaching modes and the need to align with evolving industry requirements. Conventional teaching methods often fail to cultivate the high-level competencies needed for intelligent construction. At the same time, the growing industry demand emphasizes the need for professionals skilled in human–machine collaborative design and AI-aided tools.

In this context, exploring AI-driven reform measures in civil engineering drawing education holds considerable theoretical and practical significance [2].

2. Current Teaching Situation and Issues

Current instructional practices in the “Civil

Engineering Drawing" course face significant challenges that impede both the enhancement of educational quality and the cultivation of students' comprehensive competencies.

2.1 Course Overview

"Civil Engineering Drawing" is offered in the first semester of the freshman year. As the initial core specialized course in the undergraduate curriculum, its instructional quality and difficulty level significantly shape students' preliminary understanding of civil engineering, influence their academic confidence, and contribute fundamentally to the formation of their professional identity and perception of disciplinary rigor.

In most Chinese universities, "Civil Engineering Drawing" courses typically carry a credit value ranging from 2 to 5, with total instruction hours varying between 32 and 110. For example, Chang'an University offers a curriculum integrating descriptive geometry and engineering drawing with Revit-based 3D modeling, totaling 110 hours delivered over two semesters. The first semester comprises 62 hours of theoretical instruction, while the second includes 48 hours of practical computer sessions covering CAD and Revit applications [3]. Similarly, Jiaying University allocates 2 credits and 34 contact hours to the course, with 14 hours devoted to theoretical concepts—such as point-line-plane projection and axonometric drawing—and 20 hours dedicated to software training, including CAD operation and 3D model printing techniques [4].

From a curricular perspective, this course functions as an introductory gateway to engineering design and plays a critical role in establishing students' foundational professional knowledge. Essential learning outcomes include mastering orthographic projection principles, interpreting and producing architectural construction drawings, and understanding structural drawing standards. These competencies provide essential groundwork for subsequent specialized courses such as Concrete Structure Design and Steel Structure Design, and are indispensable for the development of practical engineering capabilities.

"Civil Engineering Drawing" is offered as a 2-credit, 32-hour course in the first semester of the freshman year. As a follow-up course, "Construction Drawing Literacy" and "BIM Comprehensive Training", which focuses on CAD and Revit skills, is delivered in the second semester of the sophomore year with 48 instructional hours. Consequently, the freshman-level course is limited to theoretical instruction. The restricted timeframe necessitates a condensed schedule, requiring students to assimilate substantial material both during and outside class hours. This limitation further hinders the development of spatial thinking and practical guidance, thereby constraining the overall effectiveness of the course.

2.2 Current Status of AI Applications in the Course

At present, the application of artificial intelligence (AI) in this course remains at a preliminary stage and is primarily limited to basic teaching assistance. The Learning Terminal platform is used to facilitate activities such as class attendance, in-class and post-class discussions, and quizzes, all aimed at enhancing students' understanding of fundamental concepts and spatial relationships. Objective quiz questions are automatically graded by the system, while subjective responses are evaluated by the instructor, improving overall grading efficiency. To date, more than 20 discussion topics have been initiated, as illustrated in the Figure 1.

In terms of instructional materials, explanatory videos have been developed to address challenging topics—such as composite geometry and intersections between lines, surfaces, or multiple surfaces—which students frequently find difficult. As illustrated in the Figure 2, these videos analyze both core course content and classic exercise problems, and have been made available on the platform for students to review outside class. However, the video content remains largely static, relying mainly on explanatory narration with limited interactivity and immersive features.

A limited number of institutions have begun to integrate basic AI-assisted technologies—such as Building Information Modeling (BIM)—to leverage its intelligent and visualization capabilities. These tools help students better understand design processes and drawing documentation, thereby enhancing engagement with the discipline [5]. However, the absence of a systematic AI-supported teaching toolkit has thus far prevented real-time guidance and optimization during student design activities.

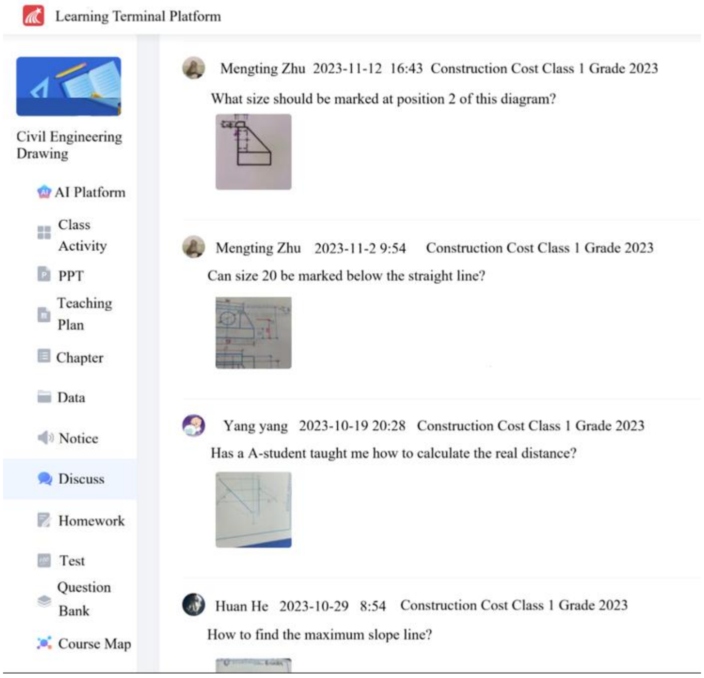

Figure 1. The Discussion Area on Learning Terminal Platform

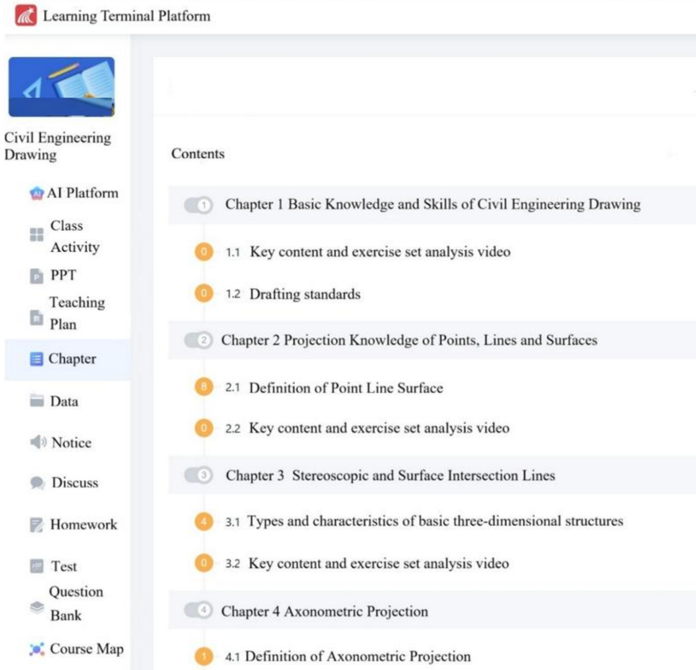

Figure 2. The Video Zone on Learning Terminal Platform

2.3 Current Teaching Status of Civil Engineering Drawing in Other Chinese Universities

Beyond AI-specific applications, the broader instructional context for Civil Engineering Drawing across Chinese higher education institutions reflects a blend of traditional and emerging digital methodologies. While many universities continue to emphasize foundational drafting competencies and manual drawing techniques, a growing number are integrating digital tools into their curricula.

At Beijing University of Chemical technology, for example, the course integrates traditional descriptive geometry with modern digital modeling, introducing software such as AutoCAD and Revit at intermediate stages. This integration, however, remains sequential rather than immersive, offering limited real-time interaction or AI-supported feedback [6]. Similarly, Tarim University employs a blended approach that combines hand-drawing exercises with BIM-based projects [7]. Nevertheless, these two instructional strands often operate in parallel with minimal algorithmic or intelligent integration.

Some institutions, such as Huazhong University of Science and Technology, have developed localized digital learning platforms capable of automated exercise correction and basic spatial simulation [8]. These tools, however, primarily function as supplements rather than core elements of the instructional framework. Similarly, Southwest Jiaotong University has introduced experimental VR-based modeling environments that enable immersive manipulation of three-dimensional structures [9]. The course “Civil Engineering Drawing” at Wenzhou Business College adopts an outcome-based education (OBE) framework and employs practical instructional approaches—including planar modeling, simulated environments, and real-world project cases—as central teaching tools [10]. These technologies, while promising, remain under development and have not yet seen widespread adoption.

A common challenge across these institutions is the absence of a unified, AI-enhanced teaching ecosystem. Although many universities employ digital tools—including CAD, BIM, and custom quiz systems—the integration of intelligent tutoring, adaptive learning pathways, or AI-assisted design critique remains sporadic. Additional constraints, such as limited instructor familiarity with AI technologies, insufficient curricular flexibility, and uneven computational resources, further impede the scalable implementation of AI in engineering graphics education.

Thus, although awareness of AI’s potential continues to grow, its application within Civil Engineering Drawing remains largely fragmented across the nation and has not yet coalesced into a coherent or pedagogically transformative framework.

2.4 Analysis of Key Issues

Traditional instruction relies heavily on two-dimensional drawings and static physical models to develop spatial visualization skills, requiring students to mentally convert 2D representations into three-dimensional entities—a task that proves particularly difficult for those with limited spatial reasoning abilities. For example, when teaching critical concepts such as determining the intersection of a line and a plane, instructors typically illustrate the elements on the board and explain the method for identifying the intersection point; however, students often struggle to visualize the spatial relationship between the plane and the line, leading to errors in approximately 40% of assignments. Abstract drawing principles and complex spatial relationships are difficult to convey clearly through conventional teaching methods, and the limited 32-class-hour schedule further constrains the ability to demonstrate spatial transformation processes dynamically or offer individualized guidance. As a result, students frequently achieve only a superficial understanding of drafting knowledge and exhibit underdeveloped spatial imagination, leaving many unable to accurately interpret complex engineering drawings.

The scarcity of practical resources represents another significant challenge. Although over ten physical models have been developed for in-class use to aid spatial understanding—covering approximately twenty basic structural components—their capacity to represent complex architectural structures remains limited. Adjustments to one element often require redesigning the entire assembly, reducing their flexibility and educational utility. As a result, these models do not sufficiently support comprehensive understanding of three-dimensional building systems. Furthermore, without opportunities for hands-on construction or participation in full-scale engineering design processes, students struggle to relate theoretical knowledge to practical applications, which in turn constrains the development of functional spatial imagination.

The reliance on a single evaluation system remains a major constraint to improving teaching quality. The current approach depends primarily on a final paper-based drawing examination, which accounts for 60% of the grade, supplemented by regular assignments making up the remaining 40%. This system does not comprehensively or objectively reflect students’ overall capabilities. While homework and quizzes often yield satisfactory outcomes due to flexible time allowances, exam performance—which emphasizes the practical application of knowledge under timed conditions and varied problems—tends to reveal significant disparities. For example, students who perform well on assignments frequently achieve only moderate exam scores. Tasks such as reconstructing a three-view drawing from two given views of a composite solid, though not inherently difficult, often result in unexpectedly low scores due to their adaptive nature and strong demand for spatial reasoning. These outcomes highlight the need to develop assessments that more effectively measure spatial imagination, innovative thinking, and practical skills.

3. AI-Enhanced Instructional Support

To address the challenges inherent in traditional civil engineering drawing instruction, this study proposes a reform strategy centered on three core principles: AI empowerment, virtual–physical integration, and multidimensional restructuring. The approach incorporates widely used digital tools such as the virtual reality applications Doubao and Blender, alongside Building Information Modeling software including CAD and Revit. Further integration of knowledge graph systems and AI-assisted teaching modules through the Learning Terminal Platform has enabled the development of a comprehensive smart teaching framework. This system unifies theoretical, practical, and evaluative components into a cohesive instructional chain, as summarized in Table 1.

Table 1. Summary of AI Intelligent Assistance Methods

Current issues	Solution	Specific solutions
Lack of spatial imagination	Add AI intelligent software application	Using AI intelligent software such as CAD, blender, Revit to establish three-dimensional model to assist teaching
Limited practical resources	Enhance students' practical training	Innovative design of "virtual simulation+physical operation" dual track experiment, adding common cases on the platform
Single evaluation method	Improve the evaluation mechanism	Adopt multi-dimensional assessment methods such as learning general AI assisted teaching, pre class preview video, mid-term test, software modeling practice, final test, etc

3.1 Enhanced Application of AI Software

In terms of instructional content, dynamic three-dimensional modeling software—such as CAD, Blender, and Revit—is systematically integrated to transform abstract drafting principles and complex spatial relationships into immersive, interactive learning scenarios. These platforms enable students to explore virtual engineering environments, intuitively manipulate 3D models, and visualize structural and geometric properties from multiple perspectives. For instance, challenging concepts like sectional views, surface development, and spatial intersections can be dynamically simulated and interactively examined. This approach overcomes the limitations of traditional two-dimensional drawing instruction by offering a more intuitive and engaging learning experience.

By embedding these technologies, students gain a deeper conceptual understanding and improve their ability to translate theoretical knowledge into practical design skills, thereby enhancing both learning engagement and educational outcomes. Furthermore, integrating knowledge graph technology and intelligent tutoring systems (AI)—such as those implemented via the Learning Terminal Platform—can provide personalized learning pathways and adaptive content recommendations, further supporting individualized student progress.

3.2 Strengthened Practical Training

A dual-track experiential learning method combining virtual simulation and physical operation has been implemented within the curriculum. Using CAD and Blender, students deconstruct architectural assemblies and reconstruct them in virtual environments, strengthening their understanding of structural behavior and connection details. In parallel, BIM-Revit supports validation exercises where students convert digital models into axonometric and sectional views for design verification. AI-aided tools such as CivilGPT are embedded throughout these activities to provide real-time feedback, suggest optimizations, and facilitate error detection.

Furthermore, the Learning Terminal Platform hosts a growing repository of 3D case studies spanning various structural types and complexity levels, encouraging active and case-based learning. During practical sessions, an AI teaching assistant is available to offer personalized guidance, prompt reflective thinking, and support iterative improvement—effectively bridging the gap between theoretical knowledge and practical application while fostering higher-order spatial reasoning and problem-solving skills.

3.3 Improved Evaluation Mechanism

The evaluation mechanism has been restructured to move beyond reliance solely on homework and final examinations. A multidimensional approach is now employed to assess students' comprehensive abilities. Recent teaching observations indicate that while most students previously submitted homework of relatively high quality and completion, some exhibited limited spatial imagination and failed to complete assignments, with a minority showing evidence of plagiarism. Challenging sections such as sectional views, cut views, and three-view drawings frequently posed difficulties and led to errors. In contrast, foundational topics including the projection of points, lines, and surfaces, as well as the interpretation of architectural drawings, were generally well mastered.

However, final exam performance was often compromised by factors such as anxiety, time constraints, extensive question volume, and inflexible application of knowledge. Consequently, exam scores averaged approximately 50 points, with some students scoring as low as 20, and the highest achievers reaching only 80 points. When combined with homework grades, the overall final course averages remained around 70, indicating a generally unsatisfactory level of student achievement under the previous assessment system.

Students are currently evaluated through a multifaceted and multidimensional assessment system, which incorporates homework assignments, attendance tracking via the Learning Terminal Platform, pre-class video or PPT previews, key concept video explanations, mid-term tests, software modeling exercises, in-class and post-class discussions, and final examinations. Basic theoretical questions are automatically generated and timed by the Learning Terminal Platform, with responses graded automatically.

In the section diagram chapter, a practical software-based approach is adopted: students are provided with plan views of real cases to construct models, from which they generate sections or sectional views, thereby deepening their understanding of these concepts. Similarly, the three-view chapter employs modeling software such as Blender, enabling students to comprehend projection relationships from perspective views and rapidly derive methods for producing three-view drawings. Additionally, group-based peer evaluation of modeling outcomes is implemented, followed by structured discussion.

These methods not heighten student engagement and enhance three-dimensional spatial awareness, but also strengthen their ability to collaborate with AI tools in project settings and facilitate accurate assessment of knowledge acquisition. This comprehensive evaluation approach offers an objective and holistic reflection of students' competencies, thereby providing valuable insights for continuous instructional improvement.

4. Conclusion

This study addresses key challenges in traditional civil engineering drawing education—such as difficulties in cultivating spatial imagination, limited practical resources, and a uniform evaluation system—by proposing a reform strategy grounded in a framework of "AI empowerment, virtual–real integration, and multidimensional restructuring." A comprehensive smart teaching system integrating theory, practice, and evaluation has been established. By incorporating AI-enhanced instructional tools—including CAD, BIM-Revit, Blender, and Doubao—along with knowledge graph technology from the Learning Terminal Platform, innovations have been introduced across teaching content, practical training modes, and assessment mechanisms.

Empirical results demonstrate significant improvements in students' spatial imagination, design capability, problem-solving skills, and human–AI collaboration, confirming the feasibility and effectiveness of the reform. However, the implementation process also highlighted the need to strengthen AI ethics education and standardize students' use of AI tools. Future efforts will focus on enhancing collaboration with industry partners to improve the compatibility of teaching tools such as Blender with enterprise-level BIM software. Further integration of the curriculum—from foundational drafting to smart construction—will also be pursued to effectively bridge drawing skills with advanced training in intelligent modeling and digital construction. These measures are expected to support the cultivation of high-quality talent better equipped to meet the demands of intelligent construction.

In summary, AI-driven reform in civil engineering drawing education represents a necessary response to contemporary technological advancements and evolving industrial requirements. Continued refinement and further development of these initiatives will provide robust support for the education of civil engineering professionals and facilitate the broader intelligent transformation of the industry.

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