Teaching Reform and Practical Research of Road Survey and Design Course Empowered by Digitalization

Yuexin Chen[1,*], Yuwu Wang[2], Pengfei Xu[1], Ran Chai[1], Shuangquan Yang[1]

[1]Nantong Institute of Technology, Nantong 226606, China
[2]Jiangsu Tongda Road & Bridge Engineering Co., Ltd., Nantong, 226602, China

*1324982434@qq.com

Abstract. The rapid advancement of digital education presents both challenges and opportunities for the traditional teaching model of Road Survey and Design. This study explores the course's evolving role in the digital era, addressing key issues including outdated content, passive teaching methods, insufficient practical training, and rigid assessment systems. The proposed reform framework integrates modern digital tools such as GIS, GPS, CAD and Civil 3D to enhance instructional effectiveness. Through restructuring theoretical and practical components with virtual simulation technologies and implementing a project-driven teaching approach that decomposes course content into practical design tasks, the reform aims to improve student engagement and develop essential problem-solving competencies. These innovations effectively bridge the gap between academic instruction and industry requirements, fostering the development of engineering professionals equipped with digital-era capabilities. The successful implementation of these methods suggests their potential applicability for broader pedagogical transformation across engineering disciplines.

Keywords: Digital Teaching Reform, Road Survey and Design, Project-Driven Teaching.

1 Introduction

Digital education is revolutionizing teaching methodologies in civil engineering, particularly for road survey and design courses. The integration of technologies like GIS, CAD, and Civil3D presents both opportunities and challenges for curriculum development and teaching innovation [1-2]. This transformation enables educators to enhance instructional quality while preparing students for industry demands.

Recent research has significantly advanced teaching reforms through three key approaches: developing comprehensive digital resource libraries [3-4], implementing modern learning theories to strengthen practical training [5], and adopting blended learning models that combine online and case-based instruction [6-10]. These developments have established a robust foundation for curriculum enhancement, particularly in fostering students' technical competencies and innovative capacities.

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Significant gaps remain in road survey design education, including curriculum-industry misalignment, superficial teaching innovations, underutilized digital tools, and inadequate assessment methods. These issues impair both teaching quality and students' practical skill development.

This study introduces a digital reform framework featuring: (1) full-course technology integration, (2) theory-practice balanced content, and (3) improved evaluation systems. Preliminary results show 91% participation rates and 15% grade improvements, demonstrating effective industry-ready professional development through digital transformation. The model successfully bridges academic instruction and engineering practice needs while advancing pedagogical innovation.

2 The Existing Teaching Status and Existing Problems

2.1 Teaching Content is Lagging Behind

The teaching content of road survey and design courses is still at the level of traditional theoretical knowledge in many universities, and the application of digital technology in road survey and design is less involved. The content of the textbook is not updated promptly, which cannot reflect the latest technology and concepts in the industry, resulting in a disconnect between the knowledge learned by students and the actual engineering needs. For example, the application of digital technologies such as geographic information systems (GIS), global positioning systems (GPS), and computer-aided design (CAD) in road surveys and design has become an industry trend, but these contents are often ignored in course teaching.

2.2 Single Teaching Method

Traditional teaching methods are mainly classroom lectures, lacking interactivity and practice. Teachers explain theoretical knowledge in class, but students passively accept it, lacking opportunities for active participation and practical operation, resulting in students' understanding and mastery of knowledge is not deep enough. This single teaching method makes it difficult to stimulate students' interest and enthusiasm in learning, and it is not conducive to cultivating students' innovative thinking and practical ability.

2.3 Weak Practical Teaching Components

Although the road survey and design course have a strong practicality, there are many problems in the current practical teaching process. The lack of practical teaching time and the lack of sufficient guidance and feedback from students in practice lead to unsatisfactory practical teaching results. In addition, the construction of practical teaching bases is insufficient, and there is a lack of practical projects combined with practical engineering, which makes it difficult for students to apply the theoretical knowledge they have learned to practical engineering.

2.4 The Assessment Method is Unreasonable

The existing assessment methods are mainly based on the final examination, which focuses on the memory of students' theoretical knowledge and ignores the assessment of students' practical ability and innovative thinking. This assessment method cannot fully reflect the learning achievements and ability level of students and is not conducive to stimulating students' learning enthusiasm and innovation ability. In addition, there is a lack of diversity in the content and methods of assessment, which makes it difficult to meet the learning needs and characteristics of different students.

3 Curriculum Instructional Design in the Context of Digital Education

3.1 Reform the Assessment Method

Road Survey and Design is a core course in the civil engineering bridge and road specialization, covering route selection, horizontal and vertical alignment design, cross-section design, and traffic facility layout. It equips students with essential skills in route planning, alignment optimization, gradient control, and cross-section design, while also training them to proficiently apply standards for intersection design. By integrating digital tools such as GIS, GPS, CAD, and Civil 3D into traditional teaching methods, the course enhances learning outcomes, helping students efficiently grasp design principles and strengthen practical skills in virtual environments. This approach fosters innovative thinking, better prepares students for the industry's digital transformation, and boosts their competitiveness in the job market.

3.2 Reconstruct the Content of Theoretical Teaching and Practical Teaching

The Road Survey and Design course requires digital restructuring to bridge theory-practice gaps. Civil 3D and HintCAD visualize abstract concepts through dynamic alignment demonstrations, 3D gradient analysis, and GIS-based terrain evaluation, enhancing both engagement and learning outcomes. This approach strengthens students' technical understanding and decision-making skills through interactive digital tools.

Practical training utilizes virtual simulation platforms covering drone surveying to final design optimization. Students employ GIS for terrain modeling and Civil 3D for comprehensive route design, integrating multi-factor analysis. Online resources support autonomous learning, while instructors provide virtual project guidance, creating an effective "learn-apply-refine" cycle. This integrated digital framework significantly improves both technical competencies and innovative problem-solving abilities in road engineering education.

3.3 Adopt Project-driven Teaching

By decomposing horizontal alignment, vertical alignment, and cross-section design into independent projects with clearly defined knowledge points and operational steps, students' practical abilities and problem-solving skills can be effectively enhanced.

In the route selection module, students must master comprehensive considerations of terrain, geology, hydrology analysis, traffic flow, and environmental factors. Using ArcGIS to import topographic maps and traffic data, they analyze slope gradients, geological conditions, and hydrological characteristics to develop preliminary route alternatives. These are then optimized through environmental impact assessments. The final route selection report, including comparative analysis of alternatives and optimization recommendations, strengthens both analytical capabilities and practical skills.

The horizontal alignment design component focuses on training students in the design principles and combination techniques of tangents, circular curves, and transition curves. Using Civil 3D, students create road centerlines by inputting design parameters such as design speed and lane width, while optimizing alignments based on terrain and traffic requirements. Dynamic simulations verify sight distance and safety, with students submitting properly annotated horizontal alignment drawings to reinforce design competency and innovative thinking.

For vertical alignment design, students learn gradient design, vertical curve radius determination, and their impacts on driving safety. Working in Civil 3D, they generate profile views, set gradients and vertical curves according to terrain while ensuring compliance with specifications. Through sight distance and drainage performance analysis, they optimize designs and submit drawings clearly marked with gradient and vertical curve parameters, thereby deepening their understanding of vertical alignment principles.

The cross-section design module emphasizes training in lane width, shoulder width, and slope gradient determination. Students use HintCAD software to draft cross-sections, input parameters, and optimize slope designs. After analyzing stability and drainage performance to refine solutions, they ultimately submit drawings with critical parameters clearly indicated, systematically mastering cross-section design theory while improving hands-on implementation capabilities.

The specific content of the project and the skills that students need to master are shown in Table 1 below.

Table 1. Requirements for the teaching content of the project.

Serial number	Teaching content	Software	Mastered skills
1	Road routing	ArcGIS	Topographic analysis, route optimization, traffic flow assessment, environmental impact analysis
2	Graphic design	Civil3D	Plane linear design, combination of straight lines and curves, line-of-sight analysis, safety assessment
Serial number	Teaching content	Software	Mastered skills

3	Profile design	Civil3D	Longitudinal slope design, vertical curve radius determination, line-of-sight analysis, drainage performance evaluation
4	Cross-sectional design	Latitude	Lane width design, shoulder width design, slope optimization, stability, and drainage performance analysis

4 Effect Evaluation

This study evaluates learning outcomes in road and bridge engineering through longitudinal tracking of two student cohorts (2021: 32 students; 2022: 68 students) during 2023–2025. Data collection emphasized classroom engagement, assignment quality, virtual simulation skills, and satisfaction. The evaluation combined process (continuous performance tracking) and outcome (exam scores) metrics. Digital teaching reforms shifted focus from traditional exam-centric assessment to holistic process evaluation, significantly improving academic performance (see Table 2). Results demonstrate enhanced learning quality through integrated digital methodologies.

Table 2. Evaluation of teaching effectiveness.

Evaluation Dimensions	Evaluation Dimensions	Software
Student Classroom Engagement	83%	91%
Job completion quality	82%	96%
The average score of the test score	75 points	85 points
Virtual simulation skills	/	80%
Student satisfaction	88%	97%

5 Conclusions

The digital education reform of road survey and design courses has successfully integrated updated content, digital technologies, project-driven methods, and enhanced practical training, significantly improving students' learning engagement, practical skills, innovative thinking, and engineering competencies while achieving excellent teaching outcomes. Future efforts will further deepen these reforms by optimizing content and methodologies, strengthening practical components, and extending this successful model to other courses to promote comprehensive educational innovation in higher institutions, ultimately cultivating high-quality engineering professionals equipped for digital era demands and advancing the digital transformation of engineering education.

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