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Design and Application of a Virtual-Real Integrated Platform for Intelligent Construction and Landscape Design of Urban Interchanges

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Abstract: To address the pain points in urban interchange teaching at application-oriented universities, such as fragmented disciplinary knowledge, disconnected virtual and physical verification, and difficulty in transforming teaching and research outcomes, this study, guided by the Outcome-Based Education (OBE) concept and relying on the Chongqing Industry-Education Integration Virtual-Real Integrated Practical Teaching Platform, constructs an AI-enabled, multi-professional collaborative virtual simulation experiment platform for urban interchanges. The platform links three core majors—intelligent construction, environmental design, and engineering cost—and builds a four-dimensional knowledge graph of "engineering object—professional knowledge—experimental task—post competency." Around three types of experiments—vehicular underpass, overpass bridge, and under-bridge landscape—it integrates the process of "virtual cognition—simulation deduction—physical training—post application," generates competency profiles, and implements the four-stage certification of "probation—assistance—independence—mentoring." Practice shows that the platform has developed 3 virtual simulation courses, undergone 4 teaching cycles, and annually serves more than 500 student person-times and more than 200 social training person-times; the course was rated as a Chongqing first-class undergraduate course, providing a reference for AI-boosted interdisciplinary integration and the integration of science and education.

Keywords: Artificial intelligence; Interdisciplinary integration; Knowledge graph; Virtual-real integration; Integration of science and education; Urban interchange

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1. Introduction

Urban interchanges integrate underground passage support, overpass bridge construction, and landscape creation, involving multiple constraints such as structural safety, construction organization, traffic diversion, environmental quality, and cost control. They are typical complex projects with multidisciplinary intersections. Traditional teaching is segmented by major, and schemes often appear compliant within a

single discipline but conflict as a whole; high-risk links such as deep foundation pit excavation and large-tonnage lifting are difficult to carry out physically; simulation and practical training are insufficiently connected, and schemes lack verification; teaching and research outcomes are mostly deposited in the form of papers and project completion reports, making them difficult to transform into reusable resources. AI can undertake knowledge consolidation, associative retrieval, and data analysis and generate candidate schemes, but problem definition and conclusion judgment are still completed by teachers, students, and enterprise mentors. Based on this, this paper takes real interchange projects as the carrier and constructs an experimental teaching system of "knowledge graph as the foundation—three types of experiments in collaboration—four-stage virtual-real integration—four-stage evaluation feedback."

2. Current research status

In recent years, virtual simulation technology has been widely used in civil engineering experimental teaching. Wang Jia et al. summarized its role in compensating for the safety shortcomings of physical experiments in high-risk scenarios such as foundation pit excavation and bridge construction [1]; Zhou Qiang et al. introduced digital twin technology into bridge construction simulation, achieving real-time mapping and status warning for steel box girder lifting [2]; Wang Jing et al. proposed an AI-driven interdisciplinary experimental teaching model, using intelligent evaluation to improve experimental efficiency [3]; Zhang Lei et al. developed an intelligent operation evaluation system based on deep learning, achieving automatic diagnosis of operation sequences [4]; Zhang Jian et al. built a virtual simulation experimental teaching center for transportation civil engineering and explored collaborative paths among civil engineering, transportation, and environment [5]; Wang Hao et al. emphasized the importance of role division and task flow collaboration mechanisms [6].

With the development of intelligent construction, Li Guoqiang et al. constructed a virtual simulation experimental teaching system for intelligent construction in civil engineering [7]; Zhao Lijun et al. studied collaborative co-construction and sharing mechanisms of experimental resources [8]; Liu Yan et al. deepened the teaching model integrating AI with experimental processes [9]; He Wei et al. verified the feasibility of steel box girder construction simulation [10]; Chen Ming et al. expanded municipal engineering experimental scenarios under the background of smart construction sites [11]; Li Li et al. analyzed the teaching value of bridge engineering simulation [12]; Wu Di et al. strengthened digital twin and full life cycle data linkage [13]; Liu Min et al. proposed an assessment method based on process evaluation [14]; Pan Li et al. explored an experimental model of landscape-civil engineering collaboration [15].

In summary, existing research still has three shortcomings: first, it emphasizes technical tools and single-point scenarios and lacks systematic design for multi-professional collaborative teaching and research paradigms and outcome transformation mechanisms; second, there is a lack of experimental platforms for urban interchanges that connect the full chain of design—construction—operation and maintenance—landscape; third, the deep integration of the three majors and the linkage mechanism among knowledge graphs, competency evidence, and post progression have not yet been established. This paper addresses the above gaps.

3. Experimental design ideas and research methods

This experiment uses the OBE concept to backward-design teaching objectives. Corresponding to the full scenario of urban interchange reconstruction, three major experimental modules are set up: vehicular

underpass, interchange overpass bridge, and interchange spatial landscape design. They focus respectively on cultivating underground engineering construction and support design ability, bridge drawing interpretation and construction organization decision-making ability, and under-bridge space cognition and design ability. The three modules work together to simultaneously cultivate students' interdisciplinary communication and system integration abilities. In terms of knowledge organization, around the four-dimensional system of "engineering object—professional knowledge—experimental task—post competency," courses such as Tunnel and Underground Engineering, Bridge Engineering, Urban Landscape Design, and Engineering Project Management are incorporated into a unified task framework. A mechanism of "intelligent-assisted construction and school-enterprise dual-teacher verification" is adopted: AI completes knowledge consolidation, associative retrieval, and problem sorting; school and enterprise dual teachers verify against standards; and experimental difficulties and verification results are continuously fed back into the database. A total of 75 knowledge nodes and 88 knowledge associations have been built, including 21 knowledge categories, 54 core knowledge points, and 37 interdisciplinary associations. In terms of the implementation path, case-based teaching is used to raise problems, project-based training to verify, and post-based learning to test application, integrating the four-stage virtual-real research process. The platform is divided from bottom to top into the foundation layer, engine layer, application layer, and evaluation layer. The platform architecture is shown in **Figure 1**.

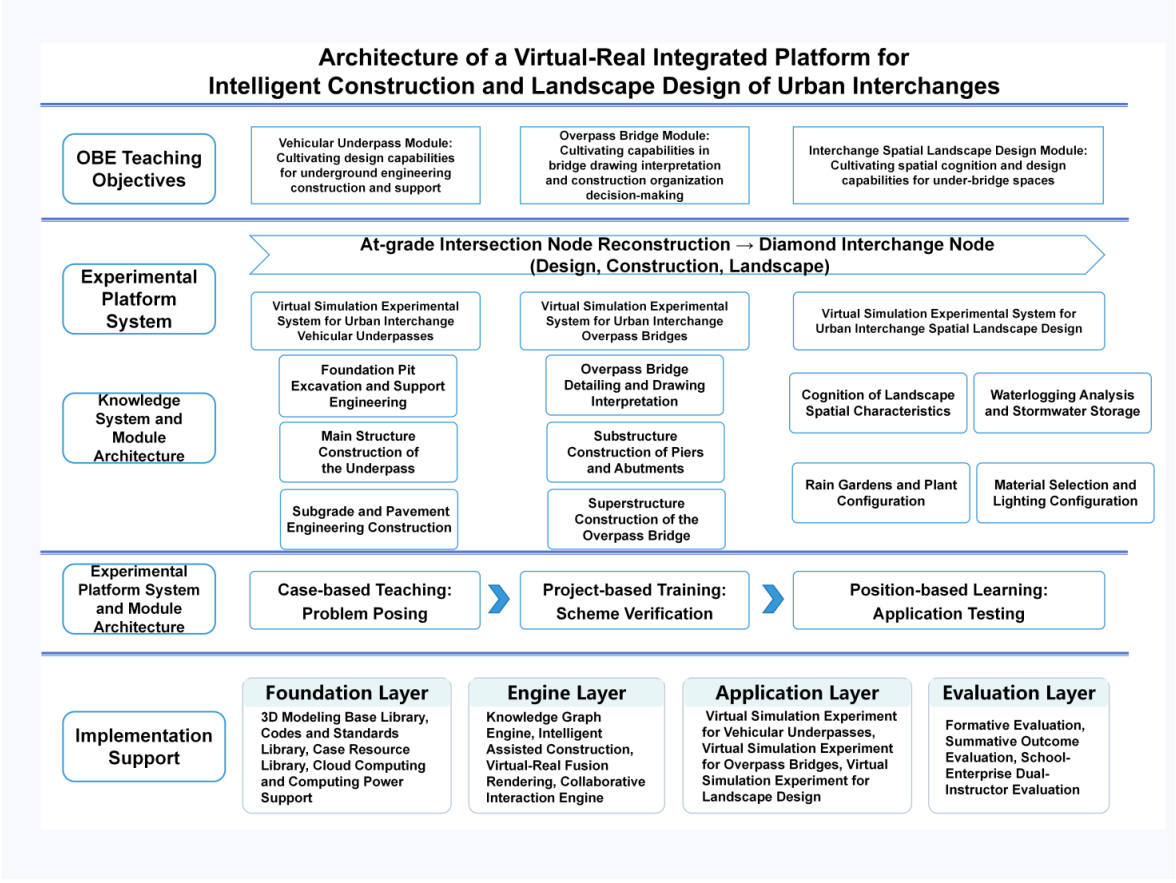


Figure 1. Overall architecture of the urban interchange virtual simulation experiment platform

4. Experimental module development and implementation

4.1. Urban interchange vehicular underpass simulation experiment

This module takes a diamond interchange (mainline underpass) as the prototype, enabling students to master the construction principles and process organization of vehicular underpasses and independently complete the comparison and selection of traffic diversion, selection of foundation pit support, main structure construction processes, and selection of subgrade and pavement technologies. Students carry out training on traffic diversion, foundation pit excavation and support, and main structure and subgrade and pavement construction, focusing on determining the sequence of support and excavation, portal elevation and clearance control, and backfilling and compaction technology. They simultaneously check traffic organization, road red lines, and quantities, and transmit construction boundary conditions to collaborating majors.

Core content includes: (1) Traffic diversion and support: AI generates multiple diversion schemes for comparison and selection, simulates anti-slide pile and retaining wall construction, and automatically verifies support parameters; (2) Main structure: simulates layered excavation and support and calculates portal elevation and clearance; (3) Subgrade and pavement: matches fill materials and compaction machinery, simulates base and surface course technologies, and outputs quantities.

4.2. Virtual simulation experiment of urban interchange overpass bridge

This module takes the interchange overpass bridge as the object and trains students to interpret plan and profile drawings and structural drawings, forming a complete chain of "from drawings to structure and from structure to construction": being able to preliminarily select pier and abutment construction schemes, master pile foundation and abutment processes, identify the criteria for major hazardous projects, and understand the requirements for prefabrication, lifting, connection, and weld inspection of steel box girders. Students carry out deduction of pile foundation and abutment construction, steel box girder prefabrication and lifting, and segment connection and acceptance, coordinate traffic diversion, temporary sites, and cost constraints, and transmit clearance and maintenance conditions to landscape tasks.

Core content includes: (1) Structural drawing interpretation: AI identifies plan and profile parameters and assists in selecting load grades and structural types; (2) Substructure construction: simulates pile foundation and abutment processes and provides the basis for determining major hazardous projects; (3) Superstructure construction: simulates steel box girder prefabrication, lifting, connection, and weld inspection; (4) Interface verification: calculates temporary land occupation and transportation organization and outputs clearance and maintenance conditions.

4.3. Virtual simulation experiment of urban interchange spatial landscape design

This module takes under-bridge space as the carrier, enabling students to understand the formation mechanism and activation logic of "negative space" and independently complete spatial diagnosis, rain garden construction, plant configuration, and collaborative lighting design. Students carry out training on the cognition of landscape spatial characteristics, stormwater retention and detention, permeable pavement, plant and material configuration, and lighting installation. In the experiment, environmental design students lead spatial creation, engineering students verify construction methods and implementation conditions, cost knowledge runs through quantity measurement and economic analysis, and collaboration runs through the scheme formation process rather than end-stage splicing.

Core content includes: (1) Negative space renovation: AI identifies space types and optimizes activation schemes; (2) Stormwater retention and detention: calculates storage capacity based on catchment paths and designs permeable pavement; (3) Plants and materials: screens shade-tolerant and flood-tolerant plants, constructs structural layers, and checks cost; (4) Lighting design: balances function and landscape and links with pipeline avoidance.

5. Experimental technology innovation

The platform achieves systematic innovation in both technical and teaching dimensions, breaking through the limitations of "single major, single scenario, and outcome evaluation," as reflected in five aspects:

5.1. AI-driven full-process intelligent assistance

The platform integrates DeepSeek-R1 and DeepSeek-VL2 models with the course knowledge base and relies on Chaoxing Fanya "Zhixue Zhonggong" to assign tasks and collect outcomes. In the underpass module, AI generates three diversion schemes based on de-identified drawings and process constraints and verifies support parameters; in the overpass bridge module, AI assists in determining major hazardous projects, simulates lifting forces and spatial interference, and provides early warning of eccentric load collisions; in the landscape module, AI identifies negative space types and estimates storage capacity. AI also collects task key points, operation records, and review opinions to provide evidence for evaluation; all its outputs are source-labeled and serve only as references to be tested, with judgment vested in teachers, students, and enterprise mentors.

5.2. Interdisciplinary knowledge graph and knowledge iteration

The knowledge graph structurally associates engineering objects, course knowledge, experimental tasks, and post competencies. The three modules are connected through a unified interface: the support and excavation parameters of the underpass affect the design boundary of piers and abutments; the clearance, lighting, and maintenance conditions of the overpass serve as inputs for the landscape; and quantities and cost run through the entire process as common constraints. The graph is not a static document. Practical difficulties, optimization conclusions, and school-enterprise review feedback are continuously fed into the database, forming an iterative mechanism of "practice—refinement—database entry—reuse," and supporting course resource construction and teaching and research topic refinement.

5.3. Multi-professional collaborative task flow and constraint transfer

Students are divided into three roles—intelligent construction engineer, environmental designer, and cost engineer—who lead the corresponding modules and clarify constraints to collaborating majors. Mandatory collaborative links are set at interfaces: support schemes must be reviewed by the structural discipline for pile foundation impacts, rain gardens must confirm pipeline avoidance, and lifting sites must confirm the sequence of landscape restoration. The three types of experiments uniformly adopt the paradigm of "task interpretation—collaborative analysis—scheme deduction—deliverable output," submit comprehensive deliverables that can be cross-verified, and systematically record interaction data to form collaborative records.

5.4. Virtual-real integration and physical verification of high-risk scenarios

The platform simulates the consequences of accidents such as deep foundation pit collapse, eccentric load collision during steel box girder lifting, waterlogging and inundation under bridges, and poor plant growth, establishing risk cognition through "trial and error—feedback—correction." Simulation does not stop at the virtual: students use the training center and physical samples to carry out process operations. When virtual and physical results deviate, they trace back to the model and original basis to iterate the scheme, forming a closed loop of "virtual cognition—simulation deduction—physical training" and compensating for the shortcoming that high-risk links cannot be carried out physically.

5.5. Process-oriented smart evaluation and "four-stage" certification

The course adopts a four-dimensional grade structure comprising pre-class preview, platform training, challenge presentation, and research innovation; collects evidence of knowledge learning, simulation operation, argumentative expression, and innovative practice; and incorporates physical training records and enterprise feedback. AI aggregates operation logs, collaborative documents, and mentor comments to generate three-level profiles at the individual, group, and course levels: individual profiles push resources to address weaknesses, group profiles assess division of labor and collaborative contributions, and course profiles identify common blind spots. In post-based learning, four-stage standards of "probation—assistance—independence—mentoring" are set, judged by task independence, evidence quality, and responsibility taking. Profile results are synchronously fed back to the knowledge graph and case library, forming a closed loop of diagnosis—linkage—certification—improvement.

6. Practical effects and analysis

Relying on platform construction, a development pattern has been established in which teaching, research, and talent cultivation promote each other and improve collaboratively.

In terms of resource conditions and operational results: 3 virtual simulation experiment courses have been built; the platform has operated smoothly through 4 teaching cycles, annually serving more than 500 student person-times and undertaking more than 200 social training person-times, with cumulative visits reaching 4,800 person-times. Four types of standardized teaching resource packages have been simultaneously created, supported by experiment guides, task work orders, industry standards, and micro-lecture videos, forming a complete resource system that supports resource sharing and reuse and makes the process traceable and verifiable.

In terms of cultivating students' comprehensive abilities, 12 interdisciplinary groups with a total of 60 students were selected for pre- and post-test comparison. With 80 points set as the passing benchmark, the student task completion rate increased from 65.0% to 93.3%, and the average interface rework frequency decreased from 3.5 to 1.5. Students were able to complete scheme justification based on process records, node verification, and cost comparison, and their practical innovation ability was significantly enhanced. They have won 8 national awards and more than 30 provincial and ministerial awards in disciplinary competitions such as the College Students' Innovation Competition and the Tunnel Design Competition.

In terms of teacher development and teaching and research outcomes: Virtual Simulation Experiment of Urban Interchange Vehicular Underpass was approved as a Chongqing first-class undergraduate course, and the platform was successfully recognized as the Chongqing Industry-Education Integration Virtual-

Real Integrated Practical Teaching Platform. The teaching team won the first prize in the National College Teachers' Metaverse Digital Teaching Innovation Competition and the first prize in the 2026 Chongqing Teaching Innovation Competition. The school and enterprises jointly built 1 national first-class course and 5 provincial and ministerial first-class courses, jointly applied for more than 10 research and teaching reform projects, and obtained more than 2 million yuan in vertical and horizontal research funds.

The platform also provides pre-employment training for new employees of industry enterprises such as Chongqing Transportation Construction Group and Chongqing Jian'an Traffic Facilities Co., Ltd., effectively shortening employees' engineering cognition cycle and improving interdisciplinary collaborative communication efficiency. In collaboration with enterprises such as Chongqing Shuwei Space and Zuozuo Architecture & Landscape, real engineering project cases are fed back into classroom teaching. Relevant construction outcomes have been exchanged and promoted at national teaching and research conferences such as the 5th National Symposium on Road Survey and Design Teaching, and the demonstration and radiation effect continues to emerge.

7. Conclusion

Taking real urban interchange projects as the carrier, this paper couples AI assistance, interdisciplinary knowledge graphs, and multi-professional collaboration mechanisms to form an experimental teaching system of three types of experiments in collaboration, four-stage virtual-real integration, and four-stage evaluation feedback, alleviating the problems of fragmented knowledge, disconnected verification, and difficult outcome transformation. Organizing content with knowledge graphs, verifying AI outputs with virtual-real scenarios, and iterating the knowledge system with practical outcomes is a feasible path for application-oriented universities to promote interdisciplinary integration and the integration of science and education. Future work will expand the application of AI in intelligent experiment generation, learning situation prediction, and graph evolution, and promote cross-school sharing.

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Disclosure statement

The authors declare no conflict of interest.

References

[1] Wang J, Li L, 2020, Application of Virtual Simulation Technology in Civil Engineering Experimental Teaching. Research and Exploration in Laboratory, 39(5): 167–170.

[2] Zhou Q, Wu D, 2022, Application of Digital Twin Technology in Bridge Construction Simulation. Construction Technology, 51(8): 67–70.

[3] Wang J, Zhang YN, 2024, Research on AI-enabled Interdisciplinary Experimental Teaching Model. Experimental Technology and Management, 41(2): 112–118.

[4] Zhang L, Liu M, 2023, Research on Intelligent Evaluation System of Experimental Operations Based on Deep Learning. The Chinese Journal of ICT in Education, 2023(2): 89–93.

[5] Zhang J, Chen M, 2021, Construction of a Multi-disciplinary Collaborative Virtual Simulation Experimental Teaching Center for Transportation Civil Engineering. Research and Exploration in Laboratory, 40(3): 189–192.

[6] Wang H, Li J, 2021, Design of Interdisciplinary Virtual Simulation Experimental Projects. Laboratory Science, 24(3): 176–179.

[7] Li GQ, Chen YY, 2023, Construction and Practice of Virtual Simulation Experimental Teaching System for Intelligent Construction in Civil Engineering. Research in Higher Education of Engineering, 2023(4): 78–84.

[8] Zhao LJ, Sun W, 2023, Research on Collaborative Co-Construction and Sharing Mechanism of Virtual Simulation Experimental Teaching Projects. Research and Exploration in Laboratory, 42(8): 223–228.

[9] Liu Y, Zhao J, 2022, Research on AI-driven Virtual Simulation Experimental Teaching Model for Engineering. China Modern Educational Equipment, 2022(15): 12–14.

[10] He W, Pan L, 2022, Development and Practice of Virtual Simulation Experiment for Steel Box Girder Construction. Experimental Technology and Management, 39(7): 198–202.

[11] Chen M, Zhang J, 2022, Application of Virtual Simulation Technology in Municipal Engineering Teaching under the Background of Smart Construction Sites. China Modern Educational Equipment, 2022(21): 98–100.

[12] Li L, Wang J, 2021, Innovative Application of Virtual Simulation Experiments in Bridge Engineering Course Teaching. Journal of Architectural Education in Institutions of Higher Learning, 30(3): 145–149.

[13] Wu D, Zhou Q, 2023, Digital Twin-driven Virtual Simulation Research on the Full Life Cycle of Transportation Engineering. Journal of Highway and Transportation Research and Development, 40(5): 132–138.

[14] Liu M, Zhang L, 2023, Construction of Virtual Simulation Experiment Assessment System Based on Process Evaluation. Experimental Technology and Management, 40(6): 201–205.

[15] Pan L, He W, 2024, Construction of a Collaborative Virtual Simulation Experiment Model for Landscape Design and Civil Engineering. Art & Design, 2024(1): 132–135.

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