DOI: 10.53469/jerp.2025.07(12).10

Innovative Practice and Exploration of Knowledge – Graph - Supported Teaching Reform in Linear Algebra

Qinxian Shi

Zhiyuan School of Liberal Arts, Beijing Institute of Petrochemical Technology, Beijing 102617, China

Abstract: ***With the rapid development of information technology, knowledge graphs have become an important tool for representing structured knowledge and have introduced new possibilities for educational reform. Drawing on practical teaching experience, this study systematically examines a model that integrates knowledge graphs into the instruction of linear algebra. It discusses the construction of the knowledge graph, related pedagogical application strategies, and the resulting implementation outcomes. Findings indicate that knowledge graphs can effectively integrate instructional resources, optimize curriculum design, and significantly enhance students' autonomous learning and practical application abilities. The model provides a valuable reference for reforming foundational courses in science and engineering within the context of smart education.***

Keywords: Knowledge Graph, Linear Algebra, Teaching Reform, Smart Education, Instructional Innovation.

1. Introduction

As a foundational discipline in modern science, linear algebra plays a vital role in fields such as signal processing, data science, and artificial intelligence. Traditional instruction in linear algebra, however, tends to prioritize theoretical completeness and computational proficiency while underemphasizing the meaningful connections between mathematical concepts and real-world applications. This imbalance often prevents students from forming an integrated cognitive structure, limits intrinsic motivation, and hinders the development of practical and innovative thinking skills.

Knowledge graph technology, an emerging approach to knowledge organization and management, offers an effective response to these challenges [1]. By structurally integrating dispersed teaching materials into a coherent knowledge network, knowledge graphs inject vitality into curriculum reform and create opportunities for improved learning experiences.

2. Theoretical Foundations for Knowledge - Graph - Based Instruction

2.1 Structuring and Visualizing Knowledge

Linear algebra contains highly systematic and interconnected concepts. For example, matrices provide essential tools for solving linear systems, while eigenvalue theory underpins matrix diagonalization. Knowledge graphs present these relationships through nodes (concepts, theorems, methods) and edges (logical relations, derivations, applications), transforming traditional linear explanations into intuitive, visual knowledge networks. Such visualization [2] enables students to identify the central role of key concepts and understand learning progressions—such as the connections among determinants, matrices, vector spaces, and quadratic forms—not as isolated topics but as logically coherent developments.

2.2 Personalized and Adaptive Learning Pathways

Smart education platforms built upon knowledge graphs record and analyze learners' behavioral data—such as time spent on each topic, exercise accuracy, and resource access frequency. These data allow for dynamic assessment of students' mastery and help identify learning gaps and individual interests. Algorithm-based recommendation systems further provide personalized learning sequences, including prerequisite videos, extended readings, application-oriented examples, and targeted exercises. This approach reflects a truly student-centered instructional philosophy and supports adaptive learning pathways.

2.3 Data-Driven Instructional Decision-Making

Knowledge graphs also support teaching decisions by offering visual dashboards that reveal students' overall progress and areas of difficulty. When a large portion of students struggle with topics such as linear dependence, teachers can adjust instruction accordingly by adding explanations, offering supplementary materials, or organizing focused discussions. This enables timely, precise, and data-driven pedagogical interventions [3].

3. Construction and Implementation of the Knowledge Graph System

3.1 Structuring the Knowledge Framework

The knowledge framework of the linear algebra course was comprehensively restructured around core modules, including determinants, matrices, linear systems, vector spaces, eigenvalue theory, and quadratic forms. The internal logic of these modules was further clarified. For instance: elementary matrix operations serve as the foundation for solving linear systems, the rank of vector sets is closely related to the structure of solutions, similarity transformations and diagonalization help simplify complex computational tasks.

These logical relationships form the backbone of the knowledge graph.

3.2 Integrating Multi-Modal Instructional Resources

Previously scattered materials—such as videos, case studies, coding demonstrations, MATLAB experiments, and online assessments—were systematically integrated into the knowledge graph framework. Each node serves as a resource hub. For example, selecting the “eigenvalue” node provides direct access to theoretical definitions, instructor explanations, computational demonstrations, hands-on experiments, and practice questions. This greatly enhances resource accessibility and coherence.

3.3 Deployment within a Smart Education Platform

The knowledge graph was embedded into the XuetangX smart education platform, enabling learners to explore content through interactive visual interfaces. With built-in learning analytics and personalized recommendation functions, the platform supports an intelligent learning environment characterized by seamless transitions between learning, practicing, and assessment [4].

4. Teaching Practice Based on Knowledge Graph Integration

4.1 Profession-Oriented Practical Task Design

Recognizing differing needs among engineering and humanities/social science students, the instructional team designed differentiated practical tasks: Engineering students completed a color-image compression project that required implementing eigenvalue decomposition through MATLAB, strengthening their understanding of eigenvalues in data compression. Humanities/social science students engaged in a “copywriting design” project, creating accessible outreach materials on linear algebra that foster skills in communication and cross-disciplinary knowledge transformation.

4.2 Collaborative Inquiry and Process-Oriented Evaluation

Group collaboration was emphasized, with 4–5 students in each team completing multiple tasks and rotating leadership roles. All project processes—planning, discussion, execution, and reflection—were recorded on the knowledge graph platform.

A reformed evaluation system was implemented, combining: teacher evaluation (50%), peer evaluation (30%), self-evaluation (20%). This system shifts assessment emphasis from correctness alone to broader competencies, including applied problem-solving, model construction, creativity, and teamwork.

5. Implementation Outcomes and Empirical Findings

5.1 Significant Improvement in Student Performance

Longitudinal comparisons of performance data from 2021 to 2024 show marked improvement following implementation of the new teaching model: the proportion of high-performing students (90–100) increased from 13.4% to as high as 26.88%, the failure rate decreased from 17.53% to 5.38%. These improvements demonstrate that the knowledge - graph - supported model effectively raises overall learning levels, especially benefiting students in the mid- and lower-performance ranges.

5.2 Enhanced Student Competence and Learning Experience

Student reflections confirmed the development of a wide range of competencies. One student noted: “Through MATLAB project practice, I not only deepened my understanding of mathematical principles but also learned how to apply them to real problems. Our group overcame challenges such as resource constraints and communication barriers, which strengthened our collaboration and problem-solving skills.” This shift from “learning mathematics” to “using mathematics” reflects the intended goals of the reform.

6. Conclusion

The deep integration of knowledge graphs into linear algebra teaching represents an effective and innovative reform strategy. Knowledge structuring and visualization help address the inherent abstraction of the subject; intelligent integration of resources and personalized recommendations promote student-centered learning; differentiated practical tasks cultivate application-oriented and innovative abilities. Empirical evidence demonstrates that this model improves student learning outcomes and promotes joint growth of teachers and learners. Future research will explore the integration of knowledge graphs with emerging technologies such as generative artificial intelligence to further advance instructional innovation.

Acknowledgement

This paper is supported by the higher education scientific research planning project “Teaching Reform and Practice of Linear Algebra Course Based on Knowledge Graph” of China Association of Higher Education in 2023 (project number: 23SX0424), and “Teaching Reform and Practice of Linear Algebra Course for New Liberal Arts” of Beijing Institute of Petrochemical Technology in 2024 (project number: XNPSYB202406002).

References

[1] Yang Wenxia, Wang Weihua, He Lang, Han Hua. Research and practice of empowering smart education with knowledge graph-a case study of “Linear Algebra” at Wuhan university of technology[J]. Research in Higher Education of Engineering, 2023, (06):111-117.

[2] Wu Zheng, Duan Huabin. Analysis of hot topics in linear algebra teaching research in China: A visual analysis based on scientific knowledge mapping[J]. Journal of Hunan University of Science and Engineering, 2021, 42(05):55-58.

[3] Pang Liang. Personalized recommendation method of online course resources for "Linear Algebra" courses based on knowledge graph[J]. Wireless Internet Science and Technology, 2025, 22(13):87-90.

[4] Wang Zuoxu. On the method of constructing teaching resources for new engineering courses assisted by knowledge graph and large language model[J]. Research in Higher Education of Engineering, 2025, (01): 40-46+110.

Author Profile

Qinxian Shi lecturer, master, research direction is applied mathematics, email: shiqinxian@bipt.edu.cn.