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Development and Implementation of an Engineering Economics Course Based on Knowledge Graphs

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Abstract: *This study focuses on the Engineering Economics course and presents a comprehensive framework for constructing a course knowledge graph. It delves into key challenges encountered in the processes of knowledge extraction, relationship mapping, and resource integration. Using a practical example of the Engineering Economics course knowledge graph, the study details the construction methods, visualization approaches, and strategies for establishing connections between knowledge points. Furthermore, in conjunction with teaching practice, it explores the diverse applications of knowledge graphs in smart learning and smart teaching, offering new perspectives and practical pathways for advancing curriculum reform.*

Keywords: *Knowledge Graph, Engineering Economics, Course Construction*

1. Introduction

As an interdisciplinary applied course that integrates engineering and economics, Engineering Economics is a core compulsory subject for majors such as Engineering Management and Construction Cost, as well as an important extension course for other related engineering disciplines. It plays a vital role in cultivating students' comprehensive abilities, systems thinking, and innovation capacity [1]. However, due to the wide scope and complexity of the course content, students often face significant learning challenges. Traditional teaching models tend to present knowledge points in a fragmented manner and lack personalized learning pathways. Although current approaches—such as online courses and blended learning—have been introduced to support conventional classroom instruction, these methods still fall short of providing precise and efficient personalized learning resources and pathways tailored to students with diverse learning needs.

With the rise of digital technologies such as big data and artificial intelligence, higher education is undergoing a significant transformation. Among these technologies, artificial intelligence, with its advantages in data analysis and pattern recognition, has become a key driver for improving educational quality. Knowledge graphs, as a foundational technology in AI applications, have shown tremendous potential in constructing multidimensional knowledge systems and tracking and analyzing learner behavior and cognitive processes. A knowledge graph is a structured knowledge base that integrates graph theory and semantic network principles. Through visualization techniques, it vividly reveals the evolution and structural relationships of knowledge. It aims to comprehensively describe, deeply explore, and accurately analyze knowledge and its interconnections [2]. One of the main advantages of knowledge graphs is their ability to present abstract knowledge in an intuitive format, providing learners with a clear learning path and facilitating the transformation of abstract concepts into structured, comprehensible knowledge [2]. This feature provides a strong technical foundation for the digital development of curricula and supports the effective implementation of personalized teaching strategies [3-5].

This paper aims to explore the framework and implementation path for constructing a knowledge graph for the Engineering Economics course. By leveraging knowledge graphs, the traditionally complex and linear course content can be transformed into a visually engaging and multidimensional knowledge network. This transformation helps students grasp the logical relationships among knowledge points more clearly, enhances engagement through dynamic presentation, and ultimately improves teaching effectiveness.

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2. Framework for Constructing the Engineering Economics Knowledge Graph

2.1 Basic Structure of the Knowledge Graph

As an emerging instructional support tool, the knowledge graph for the Engineering Economics course breaks down complex course content into concise knowledge units ("nodes") and connects them through logical relationships ("edges") to form a networked knowledge system. This system features a clear hierarchy, powerful visual representation, and high levels of flexibility and scalability.

2.2 Process of Constructing the Knowledge Graph

The construction of the knowledge graph for the Engineering Economics course is designed to support the achievement of diverse instructional objectives across knowledge acquisition, skill development, and competency cultivation. The overall approach and process are illustrated in Figure 1. First, knowledge point extraction is carried out. Guided by the course learning objectives, a top-down strategy is employed to systematically refine and organize the teaching content following the logic of "course content - knowledge units - knowledge points". Second, knowledge point association is conducted. This step involves analyzing the relationships among various knowledge points, including those within the course (such as fundamental concepts, theories, and methods), cross-disciplinary knowledge points (e.g., foundational knowledge from related subjects), and extended knowledge points (e.g., cutting-edge research and practical applications). By identifying prerequisite, correlative, and hierarchical relationships, these knowledge points and their interconnections are modeled to form the basic framework of the knowledge graph. Third, resource linking is implemented. A wide range of course-related resources, including instructional videos, test banks, and reference documents, is collected. Artificial intelligence technologies are then applied to classify and tag these resources, which are subsequently mapped to the corresponding knowledge points. Furthermore, by linking course knowledge points with massive online resources such as academic journals and books, the teaching content can be significantly enriched, offering students access to more comprehensive and diversified learning materials. Finally, precise tagging is performed. Each knowledge point is labeled with relevant tags to facilitate quick retrieval and classification. This tagging system supports the creation of clear learning paths and enables more targeted resource recommendations, thus enhancing personalized learning experiences.

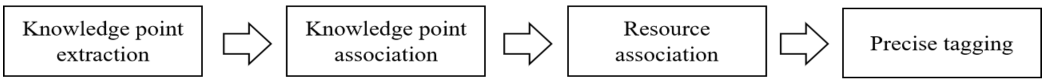

Figure 1: Knowledge graph construction process.

2.3 Key Issues in Knowledge Graph Construction

Several critical issues must be considered during the construction of the knowledge graph for the Engineering Economics course:

First, the extraction of knowledge points should be aligned with the Guidelines for Undergraduate Programs in Engineering Management in Higher Education Institutions (2015 Edition), particularly those related to Engineering Economics. These knowledge points should be supplemented and refined based on curriculum standards. For example, when tagging knowledge points, learning requirements, cognitive dimensions, and cognitive levels should be clearly defined. Learning requirements may encompass various dimensions, such as key concepts, difficult topics, exam-focused content, and ideological-political elements. In terms of mastery, cognitive dimensions can be categorized into six levels: remembering, understanding, applying, analyzing, evaluating, and creating. Furthermore, cognitive levels can be classified into factual, conceptual, procedural, and metacognitive types.

Second, the interrelation of knowledge points must be considered systematically. As a cross-disciplinary subject, Engineering Economics draws upon multiple fields of knowledge. Therefore, the mapping of knowledge points should be carried out collaboratively with instructors from related courses or disciplines to construct cross-curricular connections. For instance, collaborative design with Accounting and Construction Cost Management courses can help establish meaningful knowledge mappings. Where feasible, input from subject-matter experts can further validate these interrelations to ensure their accuracy and theoretical soundness. Such rigorous validation supports instructors in designing more coherent and in-depth learning pathways, ultimately enabling students to build a more complete and logically structured knowledge system.

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Third, the quality of instructional resources must be given high priority. A set of quality standards should be developed for various types of resources to ensure their effectiveness and reliability. These standards will also facilitate flexible resource integration and the development of personalized learning paths. Moreover, technologies such as artificial intelligence (AI) can be employed to further enhance resource quality. For example, AI can be used to segment course videos, enabling automated tagging, content recognition, and knowledge point alignment. This process allows students to quickly locate targeted learning materials, thereby supporting precise and efficient learning.

3. Construction of the Knowledge Graph for the Engineering Economics Course

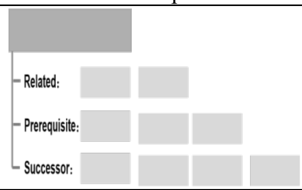
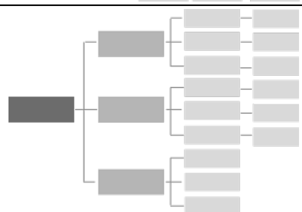
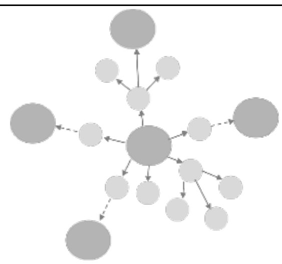
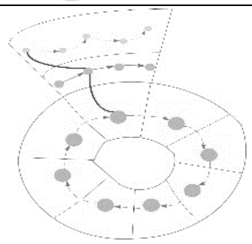
3.1 Generation and Representation of the Knowledge Graph

The knowledge graph for the Engineering Economics course can be developed by leveraging the built-in knowledge graph functionalities of commonly used teaching platforms such as Chaoxing Learning, Rain Classroom. These tools enable the transformation of existing online courses into knowledge graph-based courses.

Taking superstar learning as an example, instructors can either convert previously created online courses into knowledge graph formats or use structured template documents to import content into the platform's system, which then automatically identifies key elements and generates the corresponding knowledge graph through intelligent processing.

Moreover, knowledge graphs can be represented in various formats, including outline mode, mind map mode, graph mode, and map mode. Each representation has its features and advantages, as summarized in Table 1. During instructional activities, educators can flexibly choose the most appropriate form of presentation according to the specific needs of the teaching content and learning objectives.

Table 1: Knowledge graph representation forms.

Representation Form	Characteristics	Example
Outline mode	• It presents the instructional content in a hierarchical structure, with well-organized layers that facilitate student understanding and memorization. • It effectively highlights the core content and key teaching points of the course.	
Mind map mode	• It intuitively displays the relationships between knowledge points through graphical representation, which helps students form associative memory. • It offers flexible scalability, facilitating the recording of new ideas and connections.	
Graph mode	• It visually expresses the complex and rich relationships among knowledge points, revealing deeper connections and underlying patterns. • It represents the semantic relationships between knowledge points through nodes and edges, facilitating comprehension and mastery.	
Map mode	• It displays knowledge points based on geographic location or spatial layout, aiding the development of spatial awareness. • It presents the optimal learning path, supporting students' step-by-step progression in learning.	

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3.2 Knowledge Point Association

The association of knowledge points in the Engineering Economics course primarily involves connections within the course, across other courses, and with knowledge from real-world application domains.

First, a multi-level knowledge association system is constructed within the course itself. Through three types of semantic relationships, a prerequisite, successor, and related logical topological network of knowledge points is established. For example, for the knowledge point Equipment Replacement Analysis, the prerequisite knowledge includes Compound Interest Calculation and Dynamic Evaluation Indicators.

Second, course knowledge points are linked to key concepts in foundational and specialized courses such as Accounting and Construction Cost Management. For instance, the core concept, Financial Analysis of Construction Projects, is directly related to Financial Statements in Accounting, enabling precise knowledge point alignment and resource recommendation. With the intelligent navigation capabilities of the knowledge graph, learners can autonomously explore related knowledge domains and access a wide range of learning resources to support knowledge construction.

Third, knowledge points are associated with practical engineering applications, incorporating the latest achievements in industry as extended learning resources. For example, the knowledge point Investment Estimation for Construction Projects can be linked to up-to-date domestic and international methods such as the Comparable Group Prediction Method, enriching the curriculum with real-world insights and contemporary practices.

4. Teaching Practice of the Engineering Economics Course Based on Knowledge Graphs

The application of knowledge graphs in the teaching process is illustrated in Figure 2. By constructing the Engineering Economics course around a knowledge graph framework, fragmented instructional content and resources are reorganized into a unified, visualized knowledge network. This approach shifts the course design from traditional data-driven teaching to a knowledge-driven teaching model, placing greater emphasis on the structure, logic, and progression of knowledge. This transformation facilitates the evolution from "standardized education" to " personalized learning", aligning with the core objectives of smart education and enhancing both teaching quality and learner engagement.

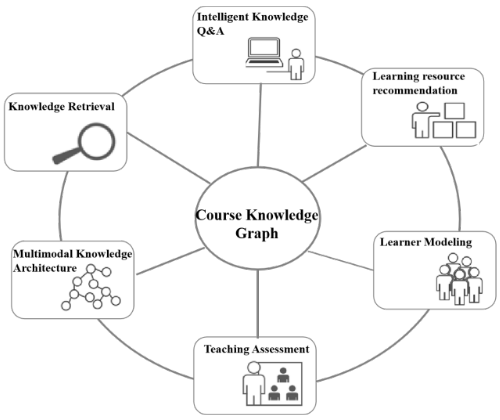

Figure 2: Application scenarios of the course knowledge graph.

4.1 Smart Learning

The core of smart learning lies in meeting learners' personalized needs and providing human-centered learning services [2]. By utilizing the course knowledge graph, students can engage in personalized and autonomous learning. They may choose to follow system-recommended learning pathways for efficient knowledge acquisition or independently plan their routes based on interests, progress, and comprehension levels-thus achieving true self-directed learning and all-round development [6].

For example, when learning the topic Investment and Composition of Construction Projects, the teaching platform can push targeted learning resources before class and provide real-time guidance and feedback. Based on students' pre-class performance, the system automatically adjusts the recommended

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learning path. This effectively addresses the shortcomings of traditional group instruction, where teachers often struggle to accommodate diverse learner needs. Furthermore, by leveraging the knowledge graph, the platform can identify students' interests and abilities, recommend suitable learning partners or groups, and foster interaction and knowledge sharing, thereby creating a self-organizing learning environment.

4.2 Smart Teaching

Based on the course knowledge graph, instructors can precisely assess students' cognitive mastery of individual knowledge units and access detailed feedback indicators, including knowledge unit achievement rates and knowledge mastery levels. This graph-based learning analytics approach equips teachers with tools for quantifying learning outcomes, supporting more targeted and personalized instruction.

Furthermore, knowledge graphs empower teachers to implement tiered instruction tailored to students' diverse competencies, interests, and learning needs. For instance, by utilizing platform features like tagging systems and cognitive dimension classifiers, instructors can systematically categorize knowledge points according to their pedagogical attributes (e.g., foundational, core, challenging, or exam-critical) and formulate targeted instructional strategies accordingly. Specifically, for students with weaker foundations, instructors may focus on essential and exam-relevant knowledge points using simplified explanations. In contrast, students with strong foundational knowledge and higher capabilities can be challenged with more complex and extended content, fostering their ability to apply engineering economics concepts to solve complex engineering problems. These strategies not only provide a systematic implementation framework for differentiated instruction but also effectively foster the development of higher-order competencies such as innovative thinking among students

5. Conclusions

As a core element of smart education systems, knowledge graphs provide transformative solutions for curriculum digital transformation. This study takes an engineering economics course as a case study to systematically elaborate a methodological framework for knowledge graph construction, focusing on key aspects including learning objective formulation, interdisciplinary knowledge network establishment, and knowledge relationship verification. The research comprehensively examines the design and implementation pathways of the course knowledge graph from three dimensions: construction mechanisms, visualization approaches, and knowledge node correlations. By leveraging knowledge graphs to enhance engineering economics instruction, this approach facilitates personalized student learning and tiered teaching strategies, thereby improving learning experiences and teaching quality while promoting the implementation of smart education.

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