# Knowledge Graph-Based Construction and Application of Three-Dimensional Intellectual Property Teaching Resources: Postprint

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## Abstract

Three-dimensional intellectual property teaching resources constitute a crucial support for cultivating compound application-oriented intellectual property talents, serving as both a new foundation for optimizing students' knowledge structures and a novel ecosystem for enhancing their practical capabilities. The specific approach to constructing such three-dimensional intellectual property teaching resources based on knowledge graphs involves utilizing Neo4j or comparable tools through three distinct phases: data collection and preprocessing, ontology construction and knowledge extraction, and data modeling and knowledge storage, thereby forming a knowledge network that reflects the intrinsic interconnections among textbooks, courseware, video lectures, laws and regulations, judicial precedents, test questions, and other pedagogical components. The practical applications of these knowledge graph-based three-dimensional intellectual property teaching resources primarily manifest in the updating and optimization of talent cultivation programs, the delivery of more targeted guidance and personalized instruction, and the enhancement of both accuracy and efficiency in question-answering processes within intellectual property pedagogy.

## Full Text

### Construction and Application of Multidimensional Intellectual Property Teaching Resources Based on Knowledge Graphs

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## Abstract

Multidimensional teaching resources for intellectual property (IP) constitute vital support for cultivating compound and application-oriented IP talents, serving as both a new foundation for optimizing students' knowledge structures and a new ecosystem for enhancing their practical capabilities. The specific path to constructing multidimensional IP teaching resources based on knowledge graphs requires tools such as Neo4j or similar platforms. Through three stages—data collection and preprocessing, ontology construction and knowledge extraction, and data modeling and knowledge storage—a knowledge network can be formed that reflects the intrinsic connections among textbooks, courseware, video lectures, laws and regulations, judicial cases, test questions, and other teaching elements.

The specific applications of these knowledge graph-based resources are primarily demonstrated in three areas: updating and optimizing talent development programs, providing more targeted guidance and personalized instruction, and improving the accuracy and efficiency of question-and-answer interactions in IP courses.

**Keywords:** Intellectual Property; Knowledge Graph; Multidimensional Teaching Resources

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## 1. The Imperative for Knowledge Graph-Based Multidimensional IP Teaching Resources

Multidimensional teaching resources represent a crucial foundation for cultivating compound and application-oriented IP talents. These resources address two critical bottlenecks in China's IP talent development: overly narrow knowledge structures and limited vocational competencies. As an organic component of the "new liberal arts" initiative, IP education is inherently a process of interdisciplinary knowledge integration. Although IP is classified as a law specialty in China's educational catalog, its disciplinary positioning remains contested. IP education emphasizes legal knowledge and skills, yet market demand clearly favors compound talents with interdisciplinary backgrounds. Consequently, there is broad consensus that IP professionals require multidisciplinary knowledge foundations.

Compound IP talents require nourishment from multidimensional teaching resources that transcend traditional disciplinary boundaries. Taking IP teaching resources as an example, the field encompasses not only law but also management, science, and other disciplines, while resource types span textbooks, courseware, video lectures, laws and regulations, judicial cases, and test banks. Multidimensional resources thus facilitate deep integration between IP and other disciplines.

However, traditional IP talent cultivation faces four major challenges. First, infrastructure remains weak. IP's technical and applied characteristics demand that professionals master both legal rules and relevant tools and methodologies. Yet most institutions inadequately invest in infrastructure, particularly software applications such as IP laboratories, patent databases, and patent analysis tools, directly impairing practical skills development. Second, practical courses are monotonous. IP's comprehensive nature requires balanced theory-practice training, yet most IP schools follow traditional law school models, producing graduates who cannot meet societal needs. Third, simulation training is inadequate. While simulation exercises are vital for practical instruction, current IP programs rely on single formats like moot courts, lacking systematic guidance and specialized faculty. Fourth, real-world drill opportunities are absent. The isolation between universities and practice departments leaves students without genuine combat experience, preventing them from developing problem-solving abilities.

Knowledge graph technology offers critical support for addressing these challenges. Knowledge graphs can integrate discrete, cross-disciplinary knowledge through nodes that record different types of practical knowledge points and their associated teaching resources, while edges express correlations between knowledge points and resources. This approach achieves efficient knowledge-resource integration, clarifies course knowledge structures, and creates vivid knowledge networks. The construction process essentially connects diverse information types into a relational network through data mining, knowledge measurement, and visualization, enabling intuitive presentation of complex knowledge structures and multidimensional relationships between hierarchies. For compound talent cultivation involving multiple specialties, simple course concatenation cannot achieve deep integration. Instead, we must start from knowledge graphs of individual courses, identify commonalities between IP and other disciplines, merge closely related knowledge points, and design new integrated curricula.

## 2. The Role of Knowledge Graphs in Building Multidimensional IP Teaching Resources

Knowledge graphs are knowledge systems formed by connecting domain knowledge and relationships into semantic networks. Scholars define knowledge graphs as interconnected sets of concept types, entities, and their attributes. Introducing knowledge graphs effectively organizes multidimensional teaching resources and builds knowledge networks that reflect intrinsic connections among course knowledge points.

Knowledge graph technology is rapidly advancing, providing important technical support for IP teaching resource construction. By recording student-teacher and peer interactions and their results, knowledge graphs associate these behaviors with specific knowledge points, making learning path analysis straightforward. They enable simple yet effective student profiling to identify knowledge gaps, support personalized analysis and guidance, and help students understand each knowledge point's position and value within the disciplinary system. Resources built on knowledge graphs will become foundational infrastructure for digital teaching ecosystems, providing basis and support for course module reconstruction and process reengineering.

### 2.1 Construction Methods

The construction of IP course knowledge graphs can employ three approaches: top-down, bottom-up, and hybrid. The top-down method begins with existing structured data sources, extracting ontologies and schema information from quality data to add to the knowledge base. The bottom-up approach lacks predefined organizational structures, instead using knowledge extraction techniques to continuously extract and update concepts and organizational structures from data sources. The hybrid method combines both: it starts with predefined ontologies or schema layers while allowing updates and modifications as data sources expand. Given that IP teaching resources are heterogeneous and multi-sourced, the hybrid approach is preferable.

### 2.2 Technical Implementation with Neo4j

Neo4j is a high-performance NoSQL graph database that can also function as a powerful graph engine. Its graph-structured data storage efficiently handles entity relationships, supports multiple data format imports/exports (CSV, JSON, etc.), and offers a rich ecosystem of open-source tools and frameworks. Compared to traditional relational databases, Neo4j's data model flexibility allows arbitrary data modifications, facilitating later maintenance. Its storage and query capabilities are robust, and operations to extend or modify graph structures are straightforward.

Constructing IP course knowledge graphs with Neo4j is a semi-automated process. For structured data, a top-down approach directly transforms structured database contents. For unstructured data, such as provisions from the Patent Law of the People's Republic of China, a bottom-up approach uses natural language processing to identify entities (e.g., patent applicants, right holders, obligors) and their relationships. This requires both automatic recognition and manual intervention to ensure accuracy.

## 3. Construction Process for Knowledge Graph-Based Multidimensional IP Teaching Resources

The construction process comprises three fundamental steps: data collection and preprocessing, ontology construction and knowledge extraction, and data modeling and knowledge storage.

### 3.1 Data Collection and Preprocessing

Data collection encompasses laws and regulations, judicial cases, academic literature, and other sources. Data quality is paramount; accuracy and consistency ensure high-quality knowledge graphs and effective analysis results. Collected data is typically semi-structured or unstructured, often containing errors and missing information. Therefore, before importing into Neo4j, data must undergo cleaning and preprocessing, including standardization, date format conversion, missing value handling, and structural processing of text content.

### 3.2 Ontology Construction and Knowledge Extraction

Ontology construction defines terminology and concepts for the knowledge domain. Hierarchical definitions establish structures between different concepts and entity types, while relationship definitions determine connections between entity types. Attributes provide detailed descriptions of entities and relationships. Together, these provide the structural and semantic foundation for knowledge graphs. Knowledge extraction employs natural language processing and text mining to identify entities, relationships, and attributes matching ontology definitions from textual data. For IP courses, ontologies may include IP types, legal principles, judicial applications, and institutional research findings.

### 3.3 Data Modeling and Knowledge Storage

Data modeling is critical for knowledge graph construction, involving defining entities, relationships, attributes, and their structures. This enables representation of IP course content in graph databases. The process includes: (1) Node mapping and creation—each data entity corresponds to a node in the graph database, with entities representing abstract concepts or concrete instances; (2) Relationship mapping and establishment—data relationships are mapped to the graph database, requiring clear edge directionality and semantic clarity; (3) Property mapping and creation—attributes describing entities or relationships are precisely defined with appropriate data types.

After modeling, Neo4j's import tools or Cypher query language store data in the graph database, enabling various retrieval and analysis commands. This facilitates visualization of complex data, intelligent segmentation of resources, and avoids inconsistencies caused by different instructors.

[Figure 1: see original paper] Multidimensional IP Teaching Resources
[Figure 2: see original paper] IP Course Knowledge Graph Construction Process
[Figure 3: see original paper] Data Collection and Preprocessing Flow
[Figure 4: see original paper] Ontology Construction and Knowledge Extraction Flow
[Figure 5: see original paper] Data Modeling and Storage Based on Neo4j

## 4. Specific Applications of Knowledge Graph-Based Multidimensional IP Teaching Resources

### 4.1 Optimizing Talent Development Programs

Curriculum design is the core of talent development programs, which must evolve with legal reforms, emerging technologies, and upgraded practical tools. Knowledge graphs facilitate IP curriculum reconstruction and process reengineering. Based on IP course knowledge graphs, teaching teams and experts can identify core content for each course, determine knowledge point clustering and classification, delineate core versus extended learning scopes, and establish logical connections between related knowledge points across different courses.

For example, "General Theory of Patent Law" and "Patent Information Retrieval and Utilization" share closely related knowledge points, with the former providing foundational knowledge for the latter. Knowledge graphs effectively express these logical relationships, enabling orderly integration of cross-course content and eliminating redundant teaching. In China's credit-limited system, directly superimposing training programs from multiple specialties creates unsustainable burdens. Knowledge graphs help find intrinsic logic between course modules, achieve interdisciplinary integration within limited credits, and support scientific teaching plans and schedules.

### 4.2 Targeted Guidance and Personalized Teaching

The richness of multidimensional IP teaching resources offers students more choices but also increases difficulty in rapidly identifying needed knowledge. Knowledge graph tags and classifications help students easily locate required knowledge units and related resources. Knowledge maps built from knowledge graphs provide intuitive understanding of key IP concepts and relationships.

By collecting knowledge points from IP textbooks and cutting-edge literature, performing text mining, and identifying dependency structures between points, we create knowledge maps covering patents, trademarks, copyrights, and trade secrets. These maps guide students to focus on unmastered knowledge points ("learn what you don't know"). Additionally, connecting homework, exams, and course knowledge graphs establishes associations between knowledge points and individual students, enabling personalized analysis and guidance.

### 4.3 Improving Q&A Accuracy and Efficiency

Knowledge graph-based intelligent Q&A has become integral to many applications. Deep learning-based natural language processing models, particularly large language models like ChatGPT and ERNIE Bot, have further improved accuracy and efficiency. While some question the necessity of knowledge graph-based Q&A given these advances, such systems remain essential for professional domains requiring high accuracy.

Multidimensional IP teaching resources include not only static initial resources but also derived data from teaching interactions and post-class activities. Knowledge graph-based Q&A records peer interactions, forming an ever-growing question bank. This solves accuracy issues in peer interactions and timeliness problems caused by high student-teacher ratios. Specialized legal knowledge graphs and case-specific knowledge graphs can be constructed to provide intelligent guidance on IP legal rules and their application scopes, helping students master knowledge proficiently.

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*Note: Figure translations are in progress. See original paper for figures.*