Construction of a Curriculum System for University Physics Experiment Courses Integrating Knowledge Graphs

Yuguo Luan*

School of Science, Shenyang Aerospace University, Shenyang, 110135, China
Corresponding author:yuguo@sau.edu.cn

Abstract: *With the continuous development of physics and advancements in educational technology, traditional teaching models for university physics experiment courses have gradually revealed issues such as fragmented knowledge points and disconnection between theory and practice. To enhance students' systematic understanding and comprehensive application of knowledge, knowledge graphs have been introduced as an emerging educational tool within the physics experiment curriculum system. This paper analyzes the current application of knowledge graphs in physics experiment teaching, proposes new pathways for constructing experimental courses based on knowledge graphs, and designs a systematic knowledge graph curriculum system in response to the needs of student autonomous learning and teaching assessment. The study shows that knowledge graphs significantly enhance the integration of physics experiment knowledge, improve students' self-directed learning abilities, and increase teaching effectiveness. Future developments will further promote innovation and advancement in physics experiment teaching through the integration of artificial intelligence, big data, and other technologies.*

Keywords: *Knowledge graph; University physics experiment; Curriculum system construction; Autonomous learning; Teaching innovation*

Introduction

Physics experiment courses are an essential component of university physics education, aimed at deepening students' understanding of theoretical knowledge and cultivating their practical skills through experimental operations. However, traditional physics experiment teaching faces challenges such as fragmented knowledge points and a disconnection between experiments and theory, making it difficult for students to form a systematic knowledge structure. In this context, knowledge graphs, as an emerging technology for knowledge organization and visualization, can integrate knowledge points in a structured manner, helping students establish a comprehensive knowledge system and improving their understanding and transfer abilities. Therefore, exploring the integration of knowledge graphs into university physics experiment courses to build a more scientific and systematic curriculum is an important direction for current educational reform.

1. Current Application Status of Knowledge Graphs in University Physics Experiment Courses

1.1 Concept and Characteristics of Knowledge Graphs

A knowledge graph is a form of knowledge organization based on semantic networks, representing the logical relationships between knowledge points through nodes and edges, thereby constructing a complex knowledge network. Its core characteristic is the ability to systematically integrate dispersed knowledge points in a structured and visual manner, enhancing learners' understanding and mastery of knowledge. Knowledge graphs not only display hierarchical relationships and causal links between concepts but also visually present interrelated knowledge modules, helping learners establish logical connections within complex knowledge structures and deepening their understanding. For the field of physics, the structural advantages of knowledge graphs are particularly significant due to the extensive derivation of theorems, application of formulas, and experimental validation, all of which involve multilayered complex associations. Through knowledge graphs, students can clearly see how physics knowledge points interact and depend on one another, aiding them in grasping the logical framework of the discipline as a whole, enhancing their systematic thinking and comprehensive application abilities. This effectively breaks the fragmentation of knowledge points commonly seen in traditional physics teaching, significantly improving learning outcomes.

1.2 The Problem of Knowledge Fragmentation in Physics Experiment Teaching

In traditional physics experiment teaching, experiment projects are often presented as independent units, lacking organic integration with theoretical knowledge, which makes it difficult for students to deeply understand the physical principles and concepts behind the experiments during the experimental process. A prominent issue with this teaching model is that knowledge points are easily fragmented, preventing students from establishing a complete and systematic knowledge structure in their minds. Additionally, the problem of knowledge fragmentation in physics experiment teaching is reflected in the lack of intrinsic connectivity between different experimental projects. Students typically view each experiment as an isolated task, unable to effectively consolidate, expand, and apply relevant theoretical knowledge through experimental operations. This fragmented learning experience limits students' knowledge transfer abilities, hindering their capacity to apply theoretical knowledge to new experimental contexts and impeding their mastery of systematic research methods and logical thinking in complex physics experiments. Furthermore, this teaching model not only affects students' experimental operation skills but also obstructs the development of their innovative thinking. Therefore, addressing the issue of knowledge fragmentation in physics experiment teaching is of significant practical importance for improving teaching effectiveness, enhancing students' learning experiences, and promoting reform in experimental teaching.

1.3 Preliminary Application of Knowledge Graphs in Physics Experiment Courses

In response to the problem of knowledge fragmentation in physics experiment teaching, some universities and educational institutions have begun to explore the integration of knowledge graphs into physics experiment courses in recent years. This integration aims to visualize knowledge points and help students better understand the connections between experimental content and theoretical knowledge. In these preliminary applications, knowledge graphs are used to reconstruct the teaching logic of experimental projects, presenting the physical principles, experimental methods, and technical operations involved in different experiments in a graphical format. This allows students to grasp the interconnections between various experimental stages holistically. For example, certain universities have utilized knowledge graphs to integrate experimental projects in classical mechanics, thermodynamics, and electromagnetism, constructing a knowledge network diagram that enables students to understand the theoretical knowledge involved behind each experiment and its interrelations, thereby forming a systematic cognitive structure. Additionally, knowledge graphs have been used to guide students through experimental procedures, helping them clarify the relationship between experimental steps and theoretical derivation, thus improving the logicality and coherence of the experimental process.[1]

Although the application of knowledge graphs in physics experiment teaching is still in its exploratory phase, existing practices indicate that knowledge graphs can effectively mitigate the phenomenon of knowledge fragmentation in experimental teaching, aiding students in better understanding and applying physical theories during experimental operations. Furthermore, the introduction of knowledge graphs provides new ideas for the innovation and optimization of physics experiment course systems, laying a foundation for future teaching reforms.[2]

2. Teaching Practices of Integrating Knowledge Graphs into University Physics Experiment Courses

2.1 Construction Path of Knowledge Graphs in Experiment Course Design

The application of knowledge graphs in university physics experiment courses requires a systematic construction path based on course content, student cognitive characteristics, and teaching objectives. The core of constructing a knowledge graph lies in the organic integration of various knowledge points, experimental steps, and relevant theoretical backgrounds in the physics experiment course, presented visually to showcase their interrelationships. First, teachers should identify the core knowledge points within the course, such as fundamental concepts, laws, and formulas in mechanics, electromagnetism, and thermodynamics, and then modularize these knowledge points based on their interdependencies. During the modularization process, special attention should be paid to the logical connections and hierarchical structures among the knowledge points to ensure that the knowledge graph accurately represents the internal system of the physics discipline.

Next, during the experimental teaching process, teachers can progressively visualize the related knowledge modules based on the specific content of different experimental projects. Using the nodes and edges of the knowledge graph, they can intuitively display the relationships between physical concepts, experimental steps, and technical operations. For instance, when teaching electromagnetism experiments, teachers can utilize knowledge graphs to illustrate the connections between magnetic fields, electric fields, and Lorentz forces, enabling students to better understand the physical principles behind the experimental steps while operating experimental instruments. Additionally, the construction of the knowledge graph should consider the effective integration of theoretical knowledge with experimental operations, facilitating the application of abstract theoretical knowledge into concrete experimental processes and helping students organically connect theory with practice.

Moreover, the design of knowledge graphs should fully accommodate the varying needs of students at different learning stages by providing graphs of varying complexity to match their cognitive levels. In the initial stages, knowledge graphs should focus on mastering core concepts and developing basic experimental skills; whereas in advanced stages, the graphs can gradually increase in complexity and interconnectivity, enhancing students' ability to integrate knowledge from multiple disciplines. This tiered and progressive construction path for knowledge graphs not only helps students gradually master the complex knowledge structures in physics experiments but also provides them with a clear learning navigation system, significantly enhancing their systematic understanding of physics knowledge and the precision of their experimental operations. Through this optimized construction path, knowledge graphs can maximize their utility in teaching, promoting the comprehensive development of students' theoretical and experimental skills.[3]

2.2 Integration of Knowledge Graphs with Students' Autonomous Learning Abilities

The introduction of knowledge graphs not only brings a new perspective to experiment course design but also provides robust support for cultivating students' autonomous learning abilities. In traditional teaching models, students largely rely on teachers' explanations and guidance, lacking an overall understanding of knowledge points and the ability to explore independently. Knowledge graphs, by visualizing complex knowledge structures, help students more clearly grasp the overall framework of experimental projects and encourage them to actively explore the connections between various knowledge points during their learning process. This visualization tool enables students, during experiments, to independently study the theoretical knowledge underlying a specific experimental step through prompts and guidance in the knowledge graph or to find related supplementary materials, thereby enhancing the depth and breadth of their autonomous learning.

Additionally, knowledge graphs can serve as a powerful tool for students to self-assess their learning progress. By comparing their understanding of the knowledge points with the nodes and connections in the knowledge graph, students can determine their mastery of each point, promptly identify weak areas in their learning, and take the initiative to review and improve. In conjunction with online learning platforms, teachers can integrate knowledge graphs with post-class resources, allowing students not only to master experimental knowledge through the graphs but also to design their own learning paths based on the graphs, selecting appropriate learning resources and supplementary materials for further exploration. This autonomous learning model based on knowledge graphs significantly enhances students' learning efficiency, increases their initiative, and fosters independent thinking. Moreover, with the help of knowledge graphs, students are better equipped to analyze and solve problems independently when facing complex experimental tasks, developing systematic thinking patterns. This enhancement of autonomous learning abilities not only improves students' performance in physics experiments but also lays a solid foundation for their future research endeavors.

2.3 Application of Knowledge Graphs in Teaching Assessment

The application of knowledge graphs not only optimizes teaching design and enhances students' learning experiences but also provides a novel and more precise method for teaching assessment. Through knowledge graphs, teachers can gain a more intuitive and clear understanding of students' mastery of experimental knowledge and their depth of understanding of relevant concepts. Specifically, teachers can design hierarchical assessment tasks based on the interconnections among the knowledge nodes in the knowledge graph. For example, teachers may ask students to explain the relationship between a specific experimental step and the corresponding theory according to the knowledge graph, using their explanations to gauge their understanding of the underlying physical principles. Additionally, teachers can focus assessments on particular modules within the knowledge graph to evaluate students' mastery in specific knowledge areas, such as mechanics, electromagnetism, or thermodynamics.

Moreover, knowledge graphs can be utilized to dynamically track students' learning progress. By recording students' usage patterns of the knowledge graph and their learning pathways, teachers can identify which knowledge points are often overlooked or misunderstood, allowing for targeted adjustments to teaching strategies. For instance, by analyzing the time students spend on certain nodes and the frequency of their interactions, teachers can determine whether specific knowledge points require more detailed explanations and review. This data-driven, dynamic feedback helps teachers optimize content and provide timely, personalized learning guidance, ensuring that every student keeps pace with the course.[4]

In final assessments, knowledge graphs can serve as crucial reference tools for students' review and autonomous learning, helping them systematically consolidate the course content throughout the semester. Students can utilize prompts from the knowledge graph to revisit their experimental steps, reflect on the connections between experimental operations and theoretical knowledge, and engage in more focused reviews of what they have learned. Additionally, students can leverage knowledge graphs to explore extensions of knowledge, fostering interdisciplinary or cross-module thinking that deepens their understanding of course content.

By integrating knowledge graphs with teaching assessment, teachers can comprehensively and intricately evaluate students' mastery of knowledge while helping students autonomously identify their knowledge gaps and deficiencies. This assessment method promotes deeper understanding and application of physics experimental knowledge, cultivating students' systematic thinking and problem-solving abilities. Furthermore, the introduction of knowledge graphs provides a dynamic, visual evaluation system that enables teachers to adjust and optimize assessment methods in real-time, continually enhancing teaching quality. This knowledge graph-based assessment model not only improves the scientific nature of evaluations but also offers broader innovative possibilities for educational reform.

3. Innovation and Development of Knowledge Graph Integration in University Physics Experiment Course Systems

3.1 Optimization of Course Structure through Knowledge Graphs

The application of knowledge graphs in university physics experiment courses offers a fresh perspective and methodology for optimizing course structure. Traditional physics experiment courses typically teach content based on chapters or independent experimental projects, lacking systematic knowledge integration. This fragmented teaching model hinders students from developing a comprehensive understanding of the overall knowledge framework. The introduction of knowledge graphs, which systematically presents dispersed knowledge points, experimental steps, and theoretical backgrounds as nodes and edges, effectively optimizes the structure of the course system. The construction of knowledge graphs transforms physics experiment courses from isolated knowledge points into an organic knowledge network, helping students understand the interdependencies and intrinsic logical connections among various knowledge points, thereby gradually building a complete framework of physics knowledge.[5]

In the specific process of course optimization, knowledge graphs can assist teachers in reorganizing the teaching content of experiment courses, rationally integrating the knowledge modules involved in different experimental projects to create a more scientific and systematic course design. Through the relational structure of knowledge graphs, teachers can closely connect theoretical knowledge with experimental operations, enabling students to master experimental skills while deeply understanding the underlying physical principles. This structured course system not only promotes coherence in knowledge but also helps students better tackle complex experimental tasks, enhancing their comprehensive analytical and problem-solving abilities. The optimizing effect of knowledge graphs on course systems is also reflected in the design of the learning process; by presenting knowledge graphs progressively, students can systematically grasp the knowledge points at each stage, ultimately forming a systematic understanding of the experimental knowledge within the physics discipline.

3.2 Integration and Innovative Fusion of Knowledge Graph Technology with Educational Technology

With the rapid development of educational technology, the integration of knowledge graph technology and modern educational tools provides new possibilities for innovating university physics experiment courses. The combination of knowledge graphs with artificial intelligence (AI), big data, and virtual reality (VR) significantly enhances the interactivity and intelligence of physics experiment teaching. For instance, by utilizing AI algorithms to analyze students' learning data, teachers can dynamically adjust the structure of the knowledge graph, helping students customize personalized learning pathways based on their progress and cognitive abilities. Additionally, AI technology can generate personalized learning suggestions in real time, guiding students to reinforce weak areas and further improve their autonomous learning outcomes.

The integration of virtual reality technology with knowledge graphs offers a novel teaching experience for physics experiment courses. Through virtual experiment platforms, students can conduct experiments in a virtual environment and interact in real time with the knowledge graph, clearly understanding the theoretical principles behind each experimental step. VR technology breaks the time and space constraints of physical experiments, allowing students to repeatedly conduct experimental operations in a virtual lab, thereby enhancing their mastery of knowledge. This immersive learning experience not only increases students' interest in learning but also enhances the intuitiveness and effectiveness of experimental teaching. The combination of knowledge graphs and virtual reality makes physics experiment courses more flexible and diverse, catering to the learning needs of students at different levels.[6]

Furthermore, the application of big data technology provides robust support for the dynamic updating of knowledge graphs. By collecting and analyzing data during the experimental teaching process, teachers can optimize the content and structure of the knowledge graph based on students' learning conditions, ensuring it reflects students' progress and needs in real time. Big data analysis can also provide a basis for evaluating teaching effectiveness, helping teachers better understand students' mastery of knowledge and the rationality of course design.

Conclusion

This paper, based on an in-depth analysis of knowledge graph technology, explores its application in university physics experiment courses and its role in optimizing course structures. The findings indicate that knowledge graphs significantly enhance students' understanding and autonomous learning capabilities regarding physics experiments, addressing the knowledge fragmentation issues present in traditional teaching. Additionally, the proposed specific pathways for integrating knowledge graphs into course design offer new insights for future reforms in physics experiment teaching. As technologies like artificial intelligence and big data continue to advance, the further fusion of knowledge graphs with educational technology will provide more possibilities for the intelligent construction of university physics experiment course systems. Future developments may incorporate personalized learning pathways and intelligent assessment systems, making the application of knowledge graphs in teaching more flexible and efficient, ultimately achieving genuine teaching innovation and comprehensive enhancement of student capabilities.

Fund Project

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2. Undergraduate Teaching Reform Project of Shenyang Aerospace University, 2024: Construction of a Curriculum System and Information System Based on Knowledge Graphs (JG241405D8).

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