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Research on Intelligent Teaching Based on Knowledge Graph of Marine Machinery Fault Diagnosis

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Abstract: To enhance the precision, personalization, intelligence, and efficiency of teaching in marine machinery fault diagnosis courses, a knowledge graph tailored for assisting classroom instruction has been developed and subsequently applied. This knowledge graph integrates multidimensional marine machinery expertise with extensive educational resources, emphasizing the systematic interconnectivity among various knowledge nodes. It facilitates personalized learning experiences in marine machinery fault diagnosis and enables precise evaluation of teaching outcomes. By incorporating select modules into the marine machinery fault diagnosis curriculum and subsequently leveraging the Likert five-point scale, an investigation was conducted to evaluate the teaching effectiveness. The results reveal a consensus among students, who unanimously agree that the application of this knowledge graph in teaching significantly improves learning efficiency, broadens their horizons, and satisfies their individual learning needs. The development and utilization of the marine machinery fault diagnosis knowledge graph strengthen students' comprehensive grasp of the overall knowledge structure, optimize teaching methodologies, and elevate teaching outcomes. This endeavor serves as a valuable reference for smart teaching in specialized courses at higher education institutions, marking a significant step forward in promoting digital transformation in education.

Keywords: Marine Machinery; Resource Management; Fault Analysis; Knowledge Graph

1. Introduction

At the 2023 World Digital Education Conference, Minister Huai Jinpeng of China's Ministry of Education pointed out that the vigorous development of digital education has not only promoted the accumulation of quality educational resources, but also invisibly accumulated vast amounts of data assets. These data, like a treasure trove, reveal the deep laws of education and teaching as well as the unique growth paths of students. This provides valuable opportunities for the education industry, enabling us to grasp the pulse of education and teaching more precisely and promote the digital transformation of education [1]. Minister Huai's speech is of great significance in promoting the digitalization level of engineering education and practical teaching.

To achieve this goal, while striving to promote the scientific and personalized development of the teaching evaluation system, it is necessary to deeply explore and utilize the vast amounts of data to create more precise learner profiles and educational knowledge graphs. This will enable us to provide customized educational plans for each student, truly implementing the principle of teaching students in accordance with their aptitudes. As a result, our education system will become more intelligent and efficient, cultivating innovative and practical talents for the new era [2,3].

Many domestic universities have embarked on the construction of knowledge graphs in their respective professional fields and achieved some substantial progress. For example, Xidian University made outstanding achievements in digital education and successfully launched an online teaching platform called "Xidian Smart Course". This platform completed the construction of detailed knowledge graphs covering 11 key professional and basic courses, providing students with more systematic and organized learning materials[4]. Tianjin Medical University also made significant progress in medical education innovation by developing a novel online learning system. This system not only comprehensively covers basic medical knowledge points and learning resources, but also enhances the intuitiveness and comprehensibility of the learning process through the use of relational graph visualization. It integrates the function of personalized adaptive learning based on the knowledge graph of basic medical knowledge, marking the birth of the first similar platform in China, greatly improving the efficiency and personalization of student learning[5].

2. Definition of Knowledge Graph and Limitations of Traditional Teaching

A knowledge graph is a unique data structure known as the "cornerstone of artificial intelligence". It captures and represents the connections between individuals and entities in the real world in a graphical manner. Within this framework, different objects, events, and concepts are abstracted into "elements" and represented by "nodes". The lines connecting these nodes represent the relationships or interactions between the elements. Therefore, the basic composition of a knowledge graph can be simplified as a combination of "node-line-node".

As the knowledge graph architecture continues to expand and deepen, various elements and their interrelationships interweave into a complex and intricate network. This network not only contains vast amounts of data, but also leverages its inherent logic and connections to provide a brand-new perspective for revealing objective laws.

Knowledge graphs can enable precision education, with application scenarios including curricula construction, specialty construction, discipline construction, professional resource library development, virtual teaching and research section construction, textbook development, and more.

There are many shortcomings and limitations in the traditional teaching of marine machinery fault diagnosis courses. These courses need to analyze various faults of engine, cultivate students' ability to respond and handle emergencies, and enhance their situational awareness in the actual management of ships. The teaching content needs to be as detailed as possible and clarify the relationships between various knowledge points (including handling methods, operational techniques, fault phenomena, etc.). In the traditional teaching model, it relies entirely on the instructor's experience on actual ships and classroom performance, which creates a great deal of uncertainty and is not conducive to students' understanding and learning of various faults and related knowledge points in operation. Even more so, personalized guidance and teaching are hardly possible.

To improve teaching effectiveness and broaden the diversity of teaching methods, the research team created resources for the China University MOOC platform and skillfully integrated teaching cases of marine machinery fault diagnosis[6]. However, we still face several challenges: the current educational resources lack sufficient subdivision, which may confuse students when exploring related knowledge and concepts; the large amount of information and its complexity increase the difficulty of students' understanding of knowledge points and burden their learning; without a visual, complete, and orderly network-like knowledge system, students find it difficult to grasp the internal connections between knowledge points, let alone deeply understanding the content with the help of interdisciplinary related knowledge; the lack of targeted learning guidance and evaluation mechanisms limits the instructor's personalized guidance for each student and makes it difficult to accurately assess teaching effectiveness and propose effective improvement measures.

3. Optimizing Traditional Teaching with a Knowledge Graph for Marine Machinery Fault Diagnosis

In traditional marine machinery fault diagnosis courses, the teaching content is structured linearly or in a tree-like fashion, focusing on teaching various faults and their handling methods chapter by chapter. The knowledge graph for marine machinery fault diagnosis comprehensively integrates teaching resources, emphasizing the systematic correlation between knowledge points. This transforms the originally linear or tree-like knowledge structure into a spatial network topology. This not only enhances students' understanding of the relevance and progression of knowledge points within this course, but also facilitates their learning and in-depth understanding of related knowledge points across different specialized courses.

The deep integration of knowledge graphs with marine machinery fault diagnosis courses enables fine-grained segmentation of teaching content, ensuring that each key knowledge point is clearly presented. Through this approach, students can quickly identify target knowledge points and thoroughly understand the relationship between the current knowledge point and other knowledge points. This learning model greatly improves students' learning efficiency and also strengthens their comprehensive mastery of the entire knowledge system.

4. Construction of a Knowledge Graph for Marine Machinery Fault Diagnosis

The research and teaching team clarified the teaching objectives and consolidated marine engineering expertise from diverse dimensions, resulting in the establishment of an interactive platform for the knowledge graph of marine machinery fault diagnosis. Furthermore, the team developed comprehensive, extensive, and systematic teaching resources, linking these resources to each node within the knowledge graph.

4.1 Process of Construction

The knowledge graph for marine machinery fault diagnosis is constructed following the procedure outlined below:

1) Integrate professional and disciplinary knowledge

Integrate cross-curricular professional and disciplinary knowledge to form a comprehensive knowledge system. Construct a clear knowledge framework through the logical relationships among knowledge points. Analyze the logical relationships between professional knowledge points to ensure coherence. Identify and optimize repetitive knowledge points among courses to reduce redundancy. Fill in knowledge gaps in the curriculum system to ensure knowledge integrity.

2) Develop target planning

Set clear teaching objectives to ensure the relevance and effectiveness of the teaching content. Analyze students' mastery of knowledge points and evaluate the achievement of course objectives.

3) Design the knowledge graph framework

Select appropriate teaching content based on the teaching mode and design the framework of the knowledge graph according to the teaching content.

4) Develop teaching resources

Produce teaching resources for each knowledge node; upload question banks and other teaching resources; match the resources with knowledge points using existing platforms[7].

5) Design and build an operational platform

Utilize online platforms provided by educational platform service providers to construct the knowledge graph for marine machinery fault diagnosis, promoting students' autonomous learning and interactive communication. Enhance students' learning engagement and efficiency through the platform's multifunctionality. Develop various online simulation teaching systems as a supplement and extension of teaching resources. Ensure that the simulation teaching system can be effectively integrated into the display and interactive operation of the knowledge graph.

4.2 Main Functions of the Knowledge Graph Interaction Platform

The knowledge graph for marine machinery fault diagnosis was completed with the help of existing platforms such as "Chaoxing" (Superstar), which integrates various self-developed learning and operation platforms, as well as collected teaching videos, documents, digital textbooks, and other resources, linking them to each node of the graph. This approach enabled the graph to possess more diverse functions.

Students can customize and plan personalized learning programs based on their individual situations. To meet the needs of diverse students, the team designed various learning roadmaps for marine machinery fault diagnosis, tailored according to their learning abilities, habits, and basic knowledge reserves. The aim is to help students systematically grasp the essential knowledge of marine machinery fault diagnosis.

Students can focus on delving into specific marine engineering business areas, accessing relevant educational resources, and achieving their self-set learning goals. The platform will present an overview of students' mastery of knowledge points, help them identify obstacles in the learning process, and continuously optimize their learning methods.

Students can effectively evaluate their own learning outcomes. With the help of the interactive platform, students can examine their personal learning progress and effects in real-time, including the completion rate and proficiency level of various knowledge points. Teachers, on the other hand, can comprehensively grasp the learning dynamics of students through the data analysis tools provided by the platform, providing a basis for implementing precise teaching guidance.

With the help of the “Chaoxing” platform, the knowledge graph can not only provide rich and diverse resource support for the teaching of marine machinery fault diagnosis courses, but also conduct a comprehensive analysis of students’ mastery of knowledge points and an in-depth analysis of their cognitive level distribution, which serves as a basis for optimizing teaching plans.

The knowledge graph for marine machinery fault diagnosis also realizes intelligent push of teaching resources related to specific knowledge points. The team has built a multi-dimensional teaching resource library around the core knowledge points, covering diverse media such as documents, animations, images, audio, videos, and various simulation operation cloud platforms. These resources are closely integrated with the knowledge points to ensure that students can easily access them at any time. Meanwhile, leveraging the inherent functional advantages of the platform, the knowledge graph for marine machinery fault diagnosis can automatically screen and recommend suitable learning resources based on students’ individual learning progress and preferences, making targeted pushes to help students broaden their horizons and enhance their learning experience.

The knowledge graph built on the “Chaoxing" platform already possesses the function of intelligent test paper generation, which can generate test papers that meet specific needs based on the knowledge points and teaching objectives of the given course. The system also supports comprehensive analysis of test papers, helping teachers quickly grasp the overall situation of the test papers and students' answers, providing a basis for implementing more precise teaching strategies. At the current stage, the intelligent test paper generation function of the knowledge graph for marine machinery fault diagnosis is still under development and improvement, and has not yet reached a complete state.

To ensure the security of learning materials and comply with various laws and regulations, the "Chaoxing" platform is also equipped with a content security review mechanism that can conduct comprehensive security checks on learning materials in various forms including text, images, and videos.

The research team is planning and developing an intelligent Q&A function. Once this function is launched, it will provide students with a simpler and more efficient auxiliary tool for marine machinery fault diagnosis learning, thereby promoting the improvement and refinement of marine machinery fault diagnosis courses and related curriculum systems.

4.3 Expansion of Node Resources

The team developed various online simulation operation platforms [8], which serve as extensions and expansions of the node resources in the knowledge graph network structure, enriching learning methods and utilizing simulations to train students' abilities in on-site drills and operations.

These teaching resources are not limited to videos, e-books, images, documents, etc. They also include various cloud-based interactive learning platforms. These cloud platforms are lightweight client-side teaching systems, where students do not need to install specific apps or plugins. Instead, they can perform various operations using mobile devices and browsers. Of course, students can also log in and operate through the control console in the practical operation site, as shown in Figure 1:

Figure 1. Online Simulation Operating System Installed on the Control Console

The team also developed a cloud-based fault diagnosis learning platform with a spatial grid topology, enriching the teaching resources associated with the graph nodes.

5. Application and Analysis

At present, the knowledge graph for marine machinery fault diagnosis is still under construction. The research team has completed the design and development of some functional modules, as well as the deployment of some node resources. This knowledge graph was introduced into the teaching process of marine machinery fault diagnosis for a class (majoring in marine engineering management), aiming to optimize teaching methods and enhance teaching effectiveness.

The team designed 50 questions and conducted a survey and research on students' learning process, learning outcomes, and learning experience using a Likert five-point scale.

For favorable questions, the scoring criteria are: 5 points for "fully agree", 4 points for "agree", 3 points for "neutral", 2 points for "disagree", and 1 point for "fully disagree". For unfavorable questions, the scoring criteria are reversed: 1 point for "fully agree", 2 points for "agree", 3 points for "neutral", 4 points for "disagree", and 5 points for "fully disagree". Based on the scores of each question, the total score of personal attitudes is calculated, and students are divided into high-scoring and low-scoring groups (the top 50% are the high-scoring group, and the bottom 50% are the low-scoring group).

After calculating the average score for each option in the survey responses of students in the high-scoring group and the average score for each option in the low-scoring group, the final form of the Likert five-point scale was composed by selecting the six items with the highest average scores from the high-scoring group and the six items with the lowest average scores from the low-scoring group.

In the scale, the formula for calculating the mean value is as follows:

$$X_j = \frac{1}{44}(X_1 + X_2 ...... + X_{44}) \quad (1)$$

X_j represents the mean value of the selected question, and X_i represents the score of the selected question in each questionnaire.

The formula for calculating the standard deviation is as follows.

$$S_i = \sqrt{\frac{1}{44}\sum_{i=1}^{44}(X_i - X_j)^2} \quad (2)$$

S_i represents the standard deviation of the question being calculated, and X_j represents the arithmetic mean of the selected question.

Upon observing the data, it was found that the mean values of all questions were greater than 4 points, and the standard deviations were all less than 1. This indicates that the students participating in the survey held a positive attitude towards the use of the knowledge graph for turbine fault diagnosis, with a good experience. They believed that it improved their learning efficiency, broadened their understanding of the overall knowledge structure, and met their individual needs. The fact that all the standard deviations were less than 1 suggests that the students' opinions and experiences were relatively consistent, indicating a similar attitude towards the use of the graph to assist their learning.

6. Conclusion

The knowledge graph, with its grid-based, three-dimensional, and open structure, offers not only a novel perspective for the development of teaching resources but also significant assistance to individual students in their personalized self-study endeavors and to instructors in their tailored teaching approaches. The development and application of the knowledge graph for marine machinery fault diagnosis have effectively consolidated complex knowledge points, clearly elucidating the intrinsic connections and logical structures among them. This has facilitated students' systematic learning of marine machinery fault diagnosis, enhanced their learning efficiency, broadened their learning horizons, deepened their learning experiences, and ultimately achieved favorable teaching outcomes. Currently, the capabilities of the knowledge graph in this domain are still undergoing continuous development and refinement, yet they have already demonstrated remarkable potential.

In the future, knowledge graphs will be more closely integrated with advanced technologies such as artificial intelligence and big data, enabling the construction of a brand-new intelligent teaching ecosystem and supporting the high-quality development of digital education in various professional fields.

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Graduate Education Teaching Reform Research Project of Liaoning Province, ((2022) 249 - 199).

References

[1] Huai, J. P. Digital transformation and the future of education: A keynote speech at the World Digital Education Conference. China Educational Technology & Informatization, 2023, (03), 3–10.
[2] Feng, Z. J., Xiong, Y. Q. Research on the development and construction mechanism of digital textbooks in higher vocational education in the new era. Chinese Vocational and Technical Education, 2024, 14, 80–85+95.
[3] Zheng, Q., Dong, B., Qian, B., et al. The State of the Art and Future Tendency of Smart Education. Jisuanji Yanjiu Yu Fazhan/Computer Research and Development, 2019, 56(1), 209–224.
[4] Wang, Q. An exploration of the four challenges and countermeasures facing the development of higher education in the era of digital intelligence. China Higher Education, 2024, Z1, 29–33.
[5] Shi, L. Y., Yan, J. R., Li, Y. M. Autonomous learning instructional design based on a basic medical knowledge graph. Basic Medical Education, 2023, 25(10), 862–865.
[6] Cong, Y., Wang, B. J., Du, T. L., et al. Research on teaching of digital-enabled ship engine room resource management. China Water Transport, 2023, (08), 48–50.
[7] Cong, Y., Wang, B. J., Zou, Y. J., Du, T. L., Bu, J. H. Research on Online Simulation Training Teaching of Onshore Marine Engine Room. Proceedings - 2022 International Conference on Education, Network and Information Technology, ICENIT 2022, 12–16.
[8] Cong, Y., Wang, B. J., Du, T. L. Simulation Experiment and Teaching Research of a Land- Based Ship Engine Room. International Journal of Information and Communication Technology Education, 2023, 19(1).