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CASE REPORT

Instructional Design and Practice of Specialized Courses Based on Knowledge Graphs—Using the Fundamentals of Electrical Engineering as a Case Study

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Abstract In the current era of rapid development of AI and Big Data, utilizing these emerging technologies to empower learning in specialized higher education courses in the electrical engineering discipline has become a hot topic among scholars. This paper constructs a ternary graph comprising knowledge, issue, and competency layers, based on knowledge graphs. Combining knowledge graphs with the instructional design of flipped classrooms and double closed-loop teaching designs, students' learning enthusiasm and efficiency can be fully unleashed. In the practical teaching of fundamentals of electrical engineering course, students' learning abilities, innovative thinking skills, and interpersonal coordination competencies significantly improved.

Keywords electrical engineering, instructional design, knowledge graphs

1 Introduction

With the development of technology and science in Chinese society, a variety of new productive forces have been widely studied as important drivers of China's economic construction, as well as industrial transformation and upgrading. Among these, talent is the most crucial factor in accelerating the development and improvement of productive forces and leading the way forward. The construction of basic education is an indispensable part of talent cultivation (Lin et al., 2021). Xi (2024), general secretary of the Communist Party of China (CPC) Central Committee, pointed out, "It is necessary to unlock the virtuous cycle of education, science and technology as well as talent in accordance with the requirements of developing new productive forces, and improve the mechanism of talent training, introduction, utilization, and national mobility." Meanwhile, technologies in the digital and intelligence fields, such as Big Data analysis, AI algorithms and applications, as well as information carrier technologies, have witnessed substantial research and application. These technologies continuously empower the traditional education field and have gradually become hot topics in educational research (Qin et al., 2020). Many studies have emphasized that digital and intelligent technologies play a significant role in transforming traditional education and positioning them as an educational singularity (Zhang, 2025). In terms of transforming educational forms, digital and intelligent technologies can efficiently allocate educational resources, optimize educational methodologies, and accurately evaluate educational effects (Moraes et al., 2024). With regard to the transformation of the education system, these technologies integrate cultivation systems, refine management mechanisms, and improve the efficiency of educational services (Ren, 2023). Therefore, in the current context of the digital and intelligent education era, it is of great significance for the modernization of socialism with Chinese characteristics to leverage these technologies to empower traditional education and cultivate new types of talent needed for China's continued development.

One of the basic components of the an education system construction is curriculum construction. Curriculum construction should meet the requirements of being high-level, innovative, and

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challenging, as well as focus on multiple aspects, such as teaching tasks, instructional methods, and educational innovation (Bhatia, 2018). Many scholars have researched optimizing curriculum design. Guo and Xue (2023) stressed that although many colleges and universities had taken teaching reform measures in aspects such as smart classrooms, curriculum system optimization, and flipped classrooms, issues such as content inadequacy and resource insufficiency in digital labor education still existed. Wang and Li (2023) harnessed digital technologies to empower education and analyzed the resulting innovations, namely, content innovation, path expansion, and method renewal. Li and Liu (2022) carried out the digital construction of an educational content system to solve problems related to the establishment of values, the improvement of educational quality, and the development of direction. Among these solutions, the integration of knowledge graphs into curriculum development has shown significant advantages. This approach is supported by educational theories, including humanistic learning, well-rounded education, and embodied cognition (Chen, 2021).

A knowledge graph refers to a graphical representation that reflects mapping relationships within knowledge, allowing for the intuitive display of connections in multiple fields of knowledge in a graphical way. Xie et al. (2024) empowered the separation problem in the three aspects of teaching, learning, and evaluation with knowledge graphs, constructed date–knowledge graph–AI (D–KG–AI) integrated architecture, and provided a theoretical basis for the integration of the three aspects. Guo et al. (2024) addressed the problem of insufficient learning–practice interoperability in the construction of a curriculum system for a signal processing major by constructing a three-element knowledge graph to achieve integration. Zhou et al. (2024) addressed the problems of difficulty in course selection and decision-making in military courses by constructing a Big Data recommendation model based on knowledge graphs that could consider multiple variables, such as interests and the abilities to provide suitable courses for trainees. Although substantial research has been conducted on the empowerment of traditional education by knowledge graph technology, there has been no research on higher education cases and designs related to the empowerment of the electrical engineering discipline by knowledge graphs. Electrical engineering disciplines are characterized by extensive knowledge bases and close coupled component relationships, making the construction of knowledge graphs a difficult task. Furthermore, electrical engineering-related professions require high stability and well-qualified professionals. Therefore, constructing knowledge graph-based teaching cases for the electrical engineering discipline is of great significance for cultivating specialized talent in the electrical field and facilitating the development of modern society.

To solve the problem of constructing an instructional design for empowering the power system major with knowledge graphs, this paper proposes a four-step knowledge graph-based curriculum system. The first step is to carry out top–down granulation of curriculum resources for the knowledge modules, knowledge units, and curriculum resource layers. The second step is to conduct bottom–up graph construction based on competencies, issues, and knowledge graphs, thus forming the knowledge graph model. The third step is to carry out instructional design and flipped classroom design. For the instructional design, a teaching architecture based on knowledge graphs is constructed, while for the flipped classrooms, a double closed-loop instructional design is constructed to complete the theoretical application scheme of knowledge graphs. The fourth step is to take actual course teaching results as a case and to conduct an evaluation across four aspects, including learning and development ability, associative thinking ability, critical thinking ability, and social work ability. The results prove the effectiveness of the instructional design for empowering the power system major with knowledge graphs.

2 Constructing Knowledge Graph Course System

Knowledge graphs, based on mathematical graph theory, consist of nodes and edges that serve to organize and represent knowledge. The advantage of knowledge graphs lies in linking scattered pieces of information through their interrelationships, integrating them into a visually interconnected knowledge network. The core of this technology is the construction of a structured knowledge system. Once established, the knowledge graph technology enables the intelligent inference of implicit knowledge based on the graph's logic.

Electrical engineering courses have three main challenges, including high complexity in knowledge modelling, rapid technological updates, and high demands for cross-course knowledge integration. Knowledge graph technology, with its hierarchical graph construction, high-dimensional modelling visualization, ease of dynamic updates, and strong knowledge connectivity, offers unique benefits in supporting the teaching of electrical courses.

2.1 | Knowledge Graph Construction Process

Based on specific specialized courses in higher education institutions, the course resources are broken down in a top–down and granular manner.

2.1.1 Determining the Knowledge Module Set

Initially, from a macro perspective, the knowledge module set for a course is determined according to the course syllabus and teaching objectives. This step involves the overall planning of the course content, including identifying the main areas and subareas of the course. Through multiple rounds of discussions and revisions, a preliminary draft of the knowledge module set has been developed, ensuring both comprehensiveness and alignment with the teaching logic. This draft covers all the core content of the course and reflects the course's teaching objectives and students' learning needs, as shown in Figure 1.

2.1.2 Decomposing the Knowledge Modules

The set of knowledge modules has been broken down into specific knowledge modules. Each knowledge module represents a core theme or concept of the course and serves as the basic unit for constructing the knowledge graph. After determining the set of knowledge modules, the paper further presents each module in detail. By deeply analyzing the internal structure and logical relationships of each module, the modules have been further refined into more specific and independent knowledge submodules. These submodules are not only highly internally relevant but also convenient for the teachers to conduct instructional design and for students to carry out autonomous learning. To ensure the accuracy and applicability of the decomposition, as well as the independence and integrity of each knowledge module, the paper provides detailed descriptions and definitions for each submodule. These descriptions and definitions not only clarify the core contents and teaching objectives of the submodules but also offer clear guidance for teachers' instructional design and students' learning activities.

2.1.3 Refining Knowledge Units

The knowledge modules or submodules are further refined into knowledge units. Each knowledge unit contains a group of related knowledge points, collectively forming a subset of the knowledge module. These units not only incorporate the core knowledge points of the course but also integrate relevant background information, application scenarios, and other pertinent contents, thereby providing students with a comprehensive and multidimensional learning experience. To ensure the coherent and systematic nature of the knowledge units, the research group has carried out detailed sorting and integration for each unit. By adjusting the order and logical relationships of the knowledge points, a clear and coherent knowledge unit system has been formed that provides strong support for the students' autonomous learning.

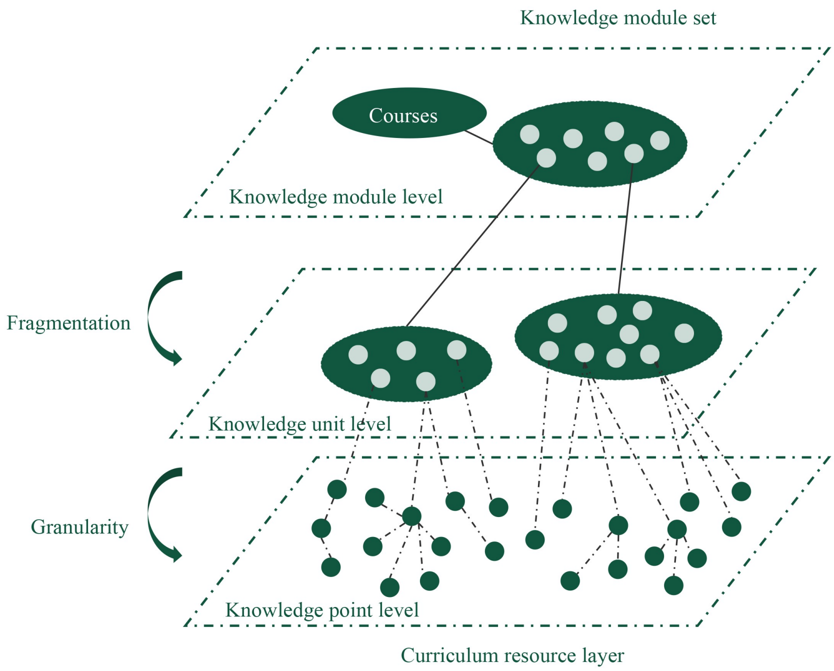

Figure 1 Construction of the knowledge graph.

2.1.4 Defining Knowledge Points

An in-depth analysis of each knowledge unit is conducted, and the key knowledge points in these units are identified. Knowledge points, as the fundamental units in a knowledge graph, not only represent the specific concepts or skills that students need to master but also embody the core values and learning objectives of the course. To ensure that the students can accurately understand and master these knowledge points, the teaching group provides detailed definitions and descriptions and formulates corresponding assessment criteria as well as learning requirements. These definitions and descriptions not only clarify the connotations and denotations of the knowledge points but also offer students clear learning objectives and assessment criteria.

2.1.5 Collecting Teaching Resources

Corresponding teaching resources, including textbooks, lecture notes, case analyses, and video lectures, are identified and sorted for each knowledge point. These resources serve as specific manifestations of knowledge points, helping students better understand and master the materials. To ensure the applicability and effectiveness of these resources, this paper classifies, sorts, and reviews the collected resources. By evaluating the resources' quality, content, and relevance to students, we identified a batch of high-quality teaching resources and established a resource database. This database not only facilitates teachers and students consulting and using resources at any time but also provides strong support for subsequent instructional design and learning.

2.2 | Building a Ternary Graph in a Bottom–Up Manner

2.2.1 Constructing the Course Knowledge Network Diagram

The course knowledge network diagram has been constructed first by analyzing the logical and dependent relationships among the knowledge points. This graph shows the connections among knowledge points, helping students understand the internal structure of knowledge. Through an in-depth analysis of causal, progressive, and parallel relationships among knowledge points, we utilize graphical tools to create the course knowledge network diagram. This diagram not only intuitively displays the internal connections and hierarchical structure of the knowledge points but also facilitates students to form a clear knowledge framework and thinking path, as shown in Figure 2.

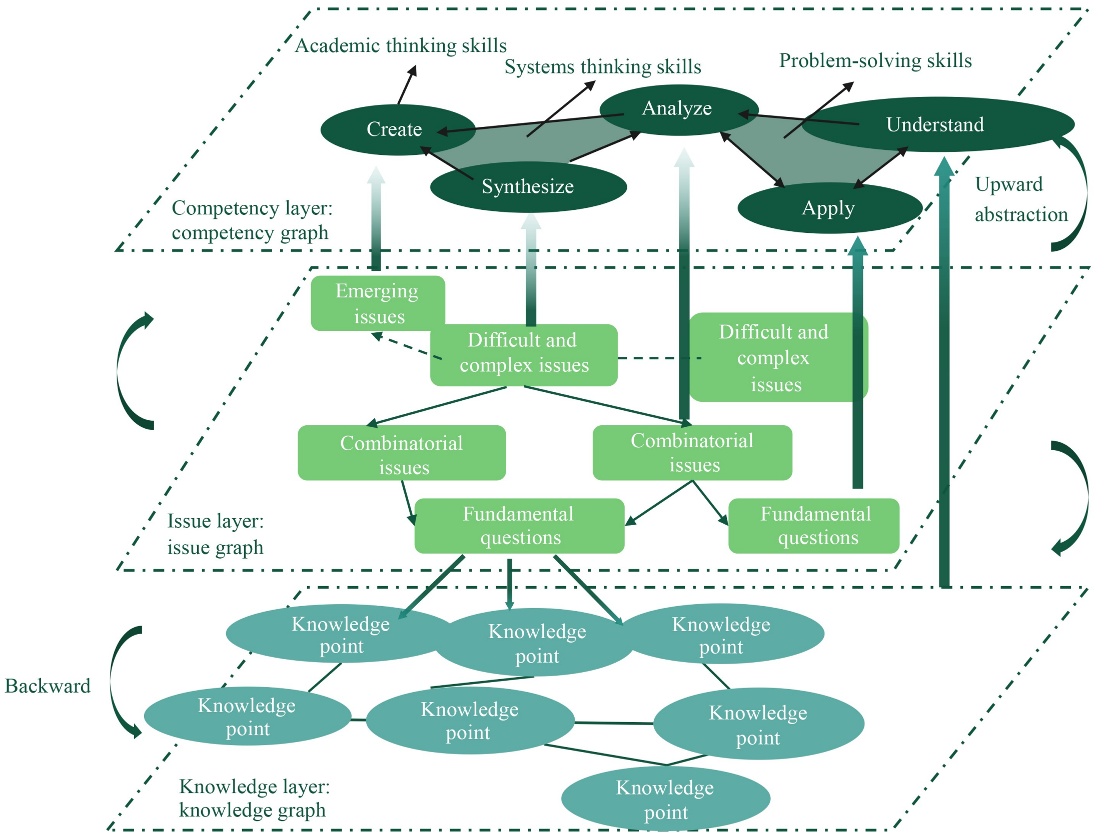

Figure 2 Construction of the course knowledge network diagram.

2.2.2 Constructing the Course Knowledge Network Diagram

Based on the course knowledge network diagram, we further constructed a question graph to stimulate students' curiosity and exploratory desire. By putting forward a series of inspiring and guiding questions, we aimed to guide students to think deeply and explore actively, thereby deepening their understanding and mastery of the knowledge points. These questions not only covered the core contents of the course but also incorporated real-life cases and scenarios, enabling students to apply their acquired knowledge to solve practical problems. The question graph would stimulate students' thinking, promote the application, and transfer of knowledge by raising questions related to knowledge points.

2.2.3 Forming the Objective and Ability Graph

To align the course objectives with students' developmental needs, we constructed an objective and ability graph. We attached great importance to combining the teaching objectives of the course and the requirements for cultivating students' abilities. Through an in-depth analysis of the course objectives and the characteristics of students, we formulated specific and quantifiable learning objectives and ability indicators. These objectives and indicators would not only provide clear guidance for teachers' instructional design but also serve as benchmarks and bases for their learning and assessment. Meanwhile, we formulated corresponding assessment criteria and feedback mechanisms to conduct timely and accurate assessments of student's learning progress and achievements. Through these efforts, we constructed an objective and ability graph that met teaching requirements and promoted students' well-rounded development. This graph clarifies the objectives and ability levels that the students should achieve during the learning process, providing a basis for teaching assessment and feedback.

The knowledge graph management, detection, recommendation, and monitoring modules were integrated with the knowledge graph as the core. By utilizing the knowledge graph, we formed the knowledge point context of each major, facilitating students' autonomous learning and self-assessment. According to the knowledge graph involved in the students' majors, self-assessment situation, and predecessor–successor relationship of courses, we accurately recommended resources, addressing learning gaps and difficulties. This approach maximizes the role of the knowledge graph platform in teaching and learning activities, effectively improves the school's informatization, and supports strategic development.

3 Instructional and Flipped Classroom Designs

3.1 | Instructional Design Framework Based on the Knowledge Graph

As shown in Figure 3, the instructional design framework has been constructed based on the knowledge graph. Blank areas in Figure 3 obscure sensitive personal information, such as facial data, that cannot be publicly disclosed. No further annotations are provided for similar instances.

The overall framework focuses mainly on three stages, including before class, during class, and after class. Before class, the knowledge graph is combined with Massive Open Online Courses (MOOCs) resources to release learning tasks. Through online autonomous learning and learning through video courseware, students complete relevant self-assessments. For students, they can understand the key and difficult points of the course in advance and condense questions, allowing them to focus on these key points during class. For teachers, they can obtain firsthand learning materials for analyzing students' learning situations. Knowledge graph helps teachers preset teaching objectives before class. It is not limited to the course but is constructed from the perspective of the electrical engineering major, taking into account the goal of fostering virtue through education. The objectives for students are established from multiple dimensions, such as knowledge, abilities, emotions, and values.

During class, stratified teaching can be carried out based on different learning situations, and adjustments can be made to key and difficult points. In this way, it is not necessary to teach all the knowledge points in class. Teachers can use the extra time to set up interactive tests to understand students' understanding of knowledge points in real-time. Interactive activities can also be carried out, or time can be given to students to provide them with more initiative space. Students can use the time saved to prepare for the flipped classroom, which provides conditions for in-depth course discussions and flipped classrooms during class later. They can also ask targeted questions and communicate about any knowledge points they are confused about. Meanwhile, ideological and political education can be integrated into courses, and cases of the craftsman spirit can be added in class. Vivid stories are used to make learning enjoyable while educating students, cultivating their sense of patriotism and national pride as well as engineering ethics, and helping them form good values and a sense of responsibility.

After class, open-ended questions and reflections are carried out to encourage students to conduct adaptive learning assignments, enabling them to obtain a higher-level learning experience. Virtual simulation platforms are used for simulated assignments to combine knowledge in school with work outside school so that students can apply what they have learned and learn while applying it. Dynamic feedback and updated learner profiles can be achieved through means such as reflection reports, mutual evaluation among teachers and students, and platform formative evaluations. Based on the course learning objectives, corresponding learning resources, and learning results can be immediately fed back to students to help them recognize their knowledge blind spots and fill in knowledge gaps.

3.2 | Double Closed-Loop Instructional Design for Flipped Classrooms

Double closed-loop teaching is generally carried out as shown in Figure 4. For the first round of the closed loop, students first conduct an online self-learning on the Xuexitong, a learning platform in China. They make use of the AI learning companion feature that accompanies them throughout the process to conduct

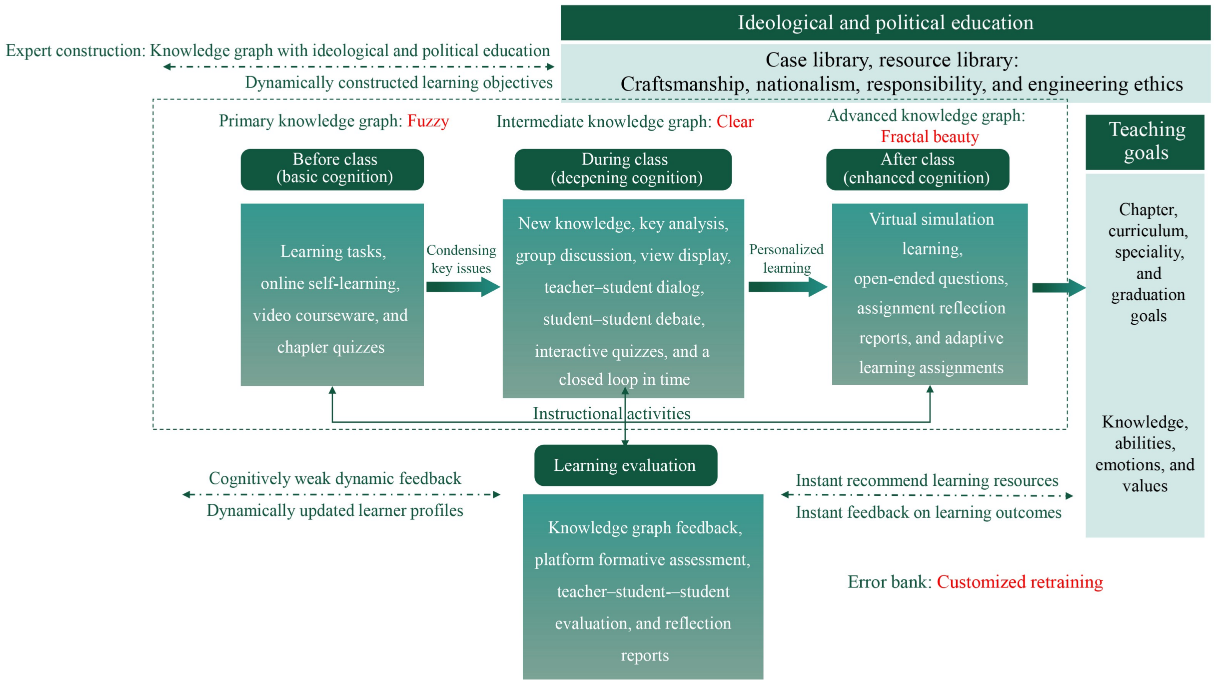

Figure 3 Instructional design framework based on the knowledge graph.

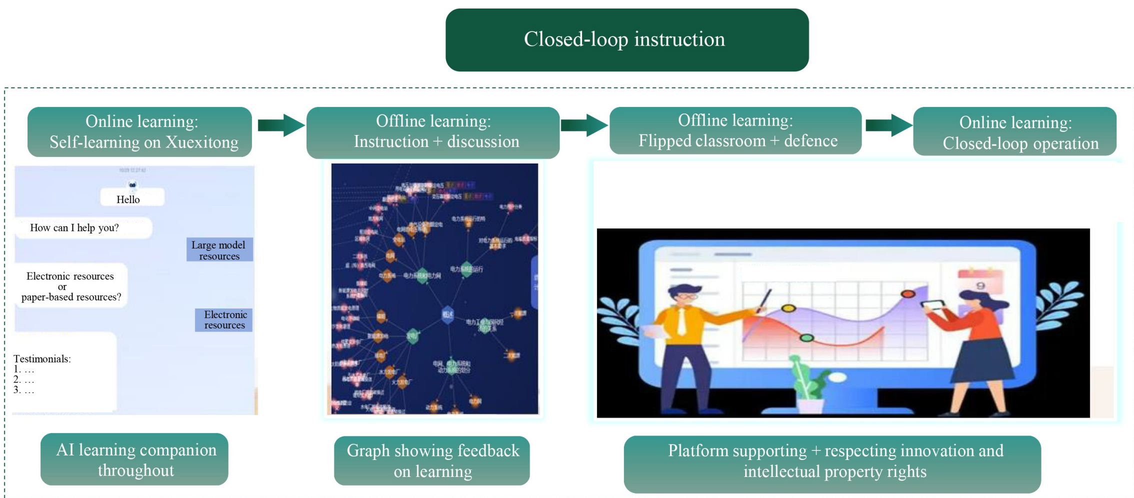

Figure 4 Double closed-loop instructional design diagram for flipped classrooms.

an efficient preview. Offline, there is normal teaching with discussion, and the knowledge graph is utilized to provide feedback on students' learning situations, thus completing the first round of the closed loop. This round focuses mainly on teaching traditional in-class theoretical knowledge, enabling students to first solidify their theoretical foundation. After mastering the basic knowledge, they can then consider expanding, diversifying, and applying knowledge.

For the second round of the closed loop, students look up information, based on open topics of problem-based learning, prepare PPT for the flipped classroom, and write relevant course reports. Then, they return to the offline flipped classroom for peer evaluation. Finally, students conduct virtual simulation learning online to complete exploratory experiments, and the second round of the closed loop starts. This round mainly aims at checking for deficiencies and making up for them in professional knowledge as well as exploratory learning. After mastering basic knowledge, students try to apply learned knowledge, use professional knowledge flexibly in practice and in dealing with actual problems, and improve their professional levels.

3.3 | Overall Evaluation and Implementation

Based on the teaching process and the construction of the teaching ecology of the above intelligent courses, the overall teaching evaluation is shown in Figure 5.

First, before class, students conduct self-learning under the guidance of the knowledge graph on Xuexitong, finish viewing the course materials and pushing the relevant assignments, and synchronously update learning situations.

Second, during class, the teaching focus is adjusted timely according to students' mastery, and students are encouraged to complete explanations of key and difficult points, engage in classroom discussions, and guide the flipped classroom.

Third, after class, students complete closed-loop reports based on the flipped classroom and relevant virtual simulation learning to complete high-level closed-loop tasks.

Fourth, a technological breakthrough is achieved through the in-depth integration of the teacher–student–machine. The course can provide personalized teaching and learning, realize precise pushing and double closed-loop teaching, and effectively conduct teaching management and personalized interventions.

Fifth, through Big Data technology, a microscopic, personalized, and digital evaluation system is established for teaching links, the learning panorama, and the dynamic monitoring of learning. The learning evaluation considers both formative and summative evaluation, providing comprehensive and precise support for the improvement of educational quality.

4 Teaching Cases and Practical Analysis

The fundamentals of electrical engineering (part 1) course has 48 class hours for 3 credits. It is a general platform course for the electrical engineering major and a basic professional course with both strong theoretical and practical aspects. Taking the production and

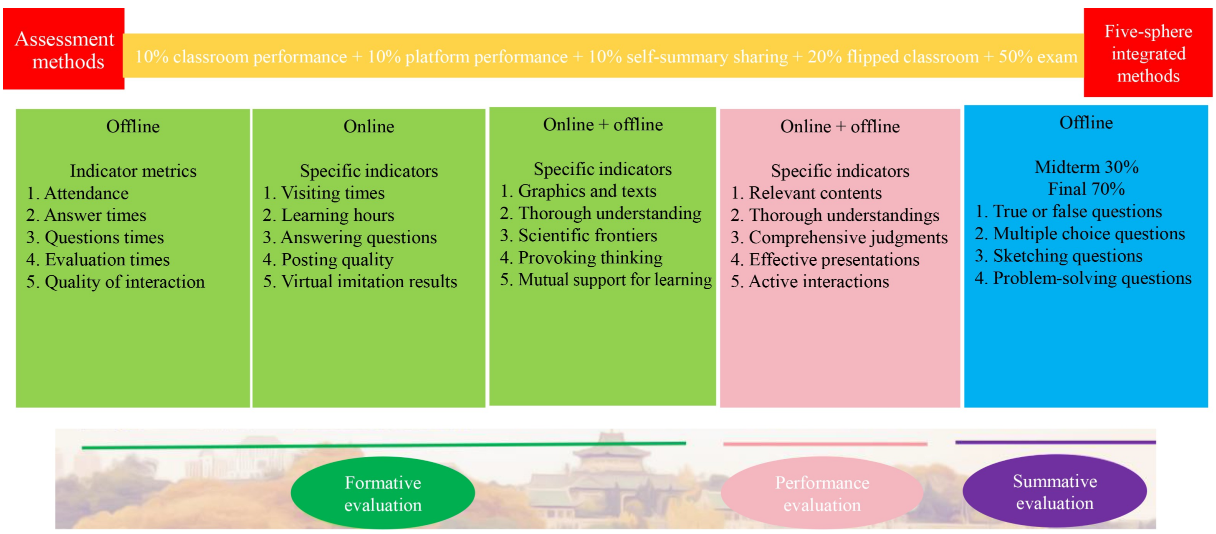

Figure 5 Overall teaching evaluation flow chart.

transmission of electrical energy and the principles of safety, reliability, high quality, and economy to ensure the operation of a power system as a main line, the course introduces the composition of the power system, its main equipment and connection modes, power flow calculations, short-circuit calculations, and the basic concepts of the steady-state operation and control of the power system. This course helps students build a conceptual understanding of the overall structure of power systems, allowing them to form preliminary awareness of both the steady-state and transient operations of power systems. Its content is similar to that of power system analysis courses, featuring a wide range of topics, strong interrelationships among topics, and high importance. It serves as a foundational knowledge base for electrical engineering students. The course is highly significant and complex in content, as well as representative, making it a typical course for electrical engineering students well suited to case-based learning. Through course design and virtual simulation experiments, the learned content is consolidated, and a foundation is laid for students' selection and learning of relevant professional courses. Figure 6 shows the course's digital sources construction. Approximately 100 students are involved in the construction of the AI course, which helps eliminate small sample bias. Since the course development is still in its early stages and has only been improved for one cohort of students, more samples will be included in future iterations of the course.

4.1 | Learning and Development Abilities

For learning and development, basic data are obtained mainly from the knowledge layer of the knowledge graph and the relevant question-answering background data of AI teaching assistants. Then, a subitem evaluation is carried out according to cognitive skills and professional skills.

4.1.1 Cognitive Skills

Based on the knowledge layer and knowledge point structure of the knowledge graph, combined with cognitive short videos and MOOC learning, the ability assessment in the dimension of cognitive skills has been completed through self-test questions.

4.1.2 Professional Skills

The key indicators are strictly benchmarked against the degree of achievement of professional accreditation and closely combined with the refined degree of achievement indicators specific to this course to complete the in-depth assessment of professional skills.

4.2 | Innovative Thinking Abilities

Innovative thinking abilities contain three aspects, including divergent thinking ability, associative

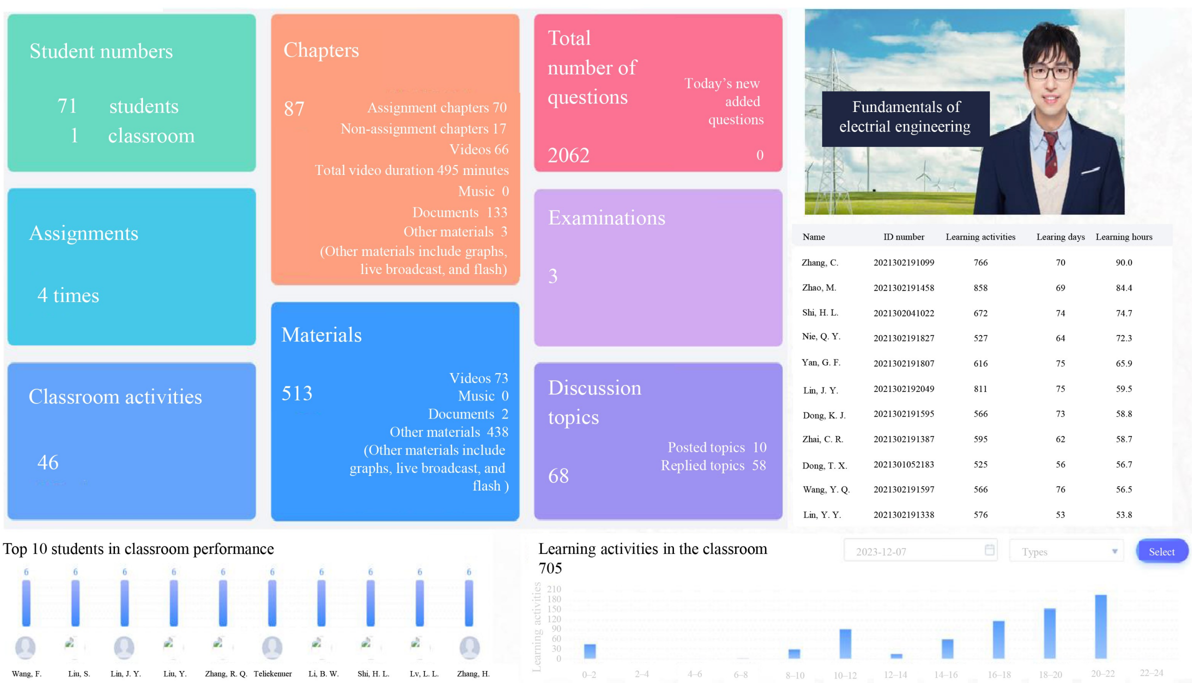

Figure 6 Digital sources construction of the fundamentals of electrical engineering (part 1) course.

thinking ability, and critical thinking ability. While focusing on classroom teaching, the course actively carried out a blended teaching mode and a flipped classroom. Through 10 to 18 open topics, in-depth discussions were conducted with students. Through reports and defences, the cultivation and assessment of the above abilities were completed.

4.2.1 Divergent Thinking Ability

A total of 10 to 18 open topics were set by constructing a problem graph. Each open topic focused on the current hot scientific and technological issues in the electrical discipline, providing measurement indicators to stimulate students' innovative inspiration, as shown in Figure 7.

4.2.2 Associative Thinking Ability

Through discussions on each open topic, associative thinking was carried out to complete the integrated understanding of the three layers, namely, knowledge–problem–goal knowledge graph. Through the effect demonstrated by specific problems, a high-level measurement of relevant abilities was completed, as shown in Figure 8.

4.2.3 Critical Thinking Ability

Adhering to the principle of placing students in the center and teachers having the leading role, critical thinking ability could be significantly improved by the unique interactive mode of students lecturing and listening to each other as well as giving lectures and evaluating in the flipped classroom and with the help of multiple forms, such as debates and defences. Combined with the continuous discussion tasks released in small private online courses, a more sufficient improvement in critical thinking ability could be achieved.

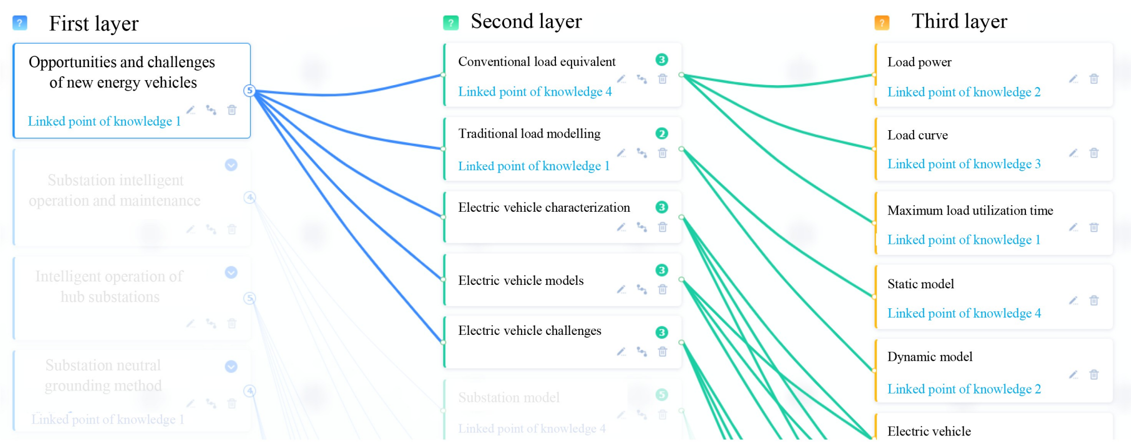

Figure 7 Divergent thinking graph structure of the fundamentals of electrical engineering (part 1) course.

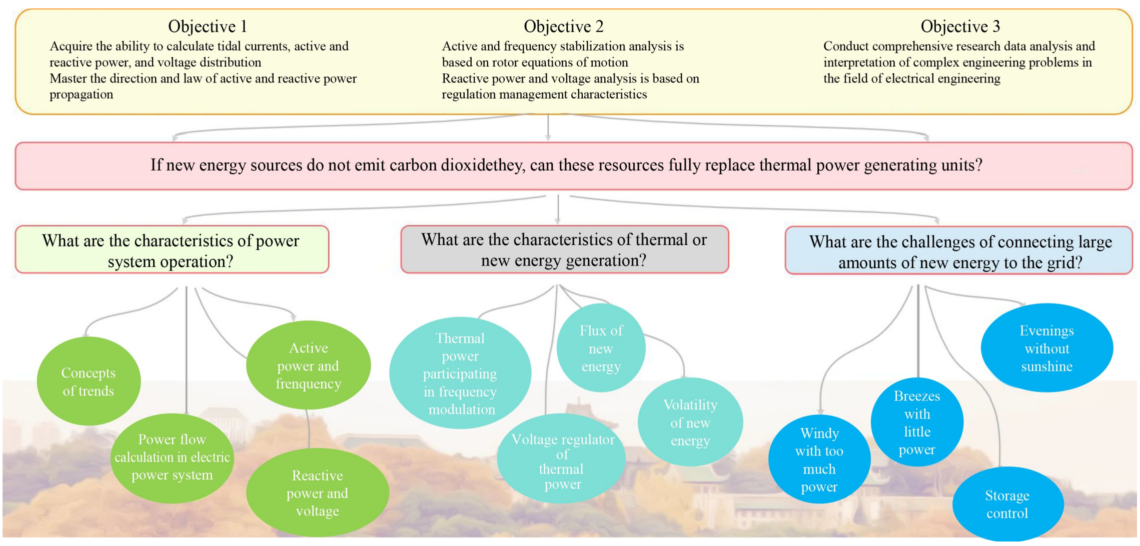

Figure 8 Three-layer knowledge graph structure of the fundamentals of electrical engineering (part 1) course.

4.3 | Interpersonal Adaptability

Interpersonal adaptability includes three aspects: emotion regulation ability, collaboration regulation ability, and situation regulation ability. The evaluation of the above abilities was completed through several preparatory processes: data search, teamwork, and discussion output in the flipped classroom.

4.3.1 Emotion Regulation Ability

Given the high-difficulty challenges of open topics in the flipped classroom, students in each study group needed to engage fully in data search, conduct in-depth discussions on practical engineering problems, accurately anchor the research direction according to the problem graph, and actively face difficulties and setbacks to adjust their emotions.

4.3.2 Collaboration Regulation Ability

In the teaching class, there were 60 students divided into 20 groups, with 3 students in each group. There was a total of 10 teaching weeks, and 2 groups of students completed reports and defences each week. During this process, the wisdom of teamwork was fully demonstrated, the division of labor within each team was carefully implemented, and the team's cohesion was strengthened.

4.3.3 Situation Regulation Ability

In the process of preparing for the flipped classroom, the students needed to face multiple and complex situations, such as group discussions, route decompositions, internal debates, external reports, and collective defences. The focus was on examining and cultivating the students' interpersonal coordination abilities within the team and comprehensively demonstrating the teamwork style.

4.4 | Evaluation

In the evaluation of the aforementioned abilities, standardized scientific scales were used rigorously to accurately measure the students' states, while qualitative observation scales were utilized skillfully to record the students' learning performances in detail. Meanwhile, the powerful data-capturing functions of professional portraits and digital-intelligent learning platforms were given full play to conduct well-rounded and refined descriptions of the student's learning behaviors and draw holographic portraits of their learning.

4.5 | Social Work Abilities

Social work abilities cover three aspects, including responsibility ability, practical ability, and task ability. In the course, these abilities are comprehensively evaluated through the in-depth integration of ideological and political cases and evaluation methods. Through a comparison of evaluations before and after class, the systematic assessment of this ability section is completed, as shown in Figure 9. A questionnaire is conducted as a pretest before the first class of the course and as a posttest after the final class. The testing period spans the entire duration of the course and provides a comprehensive reflection of improvements in students' learning outcomes and their professional interests.

4.6 | Student Feedback

After adopting knowledge graph technology, it was essential to analyze the students' feedback to better

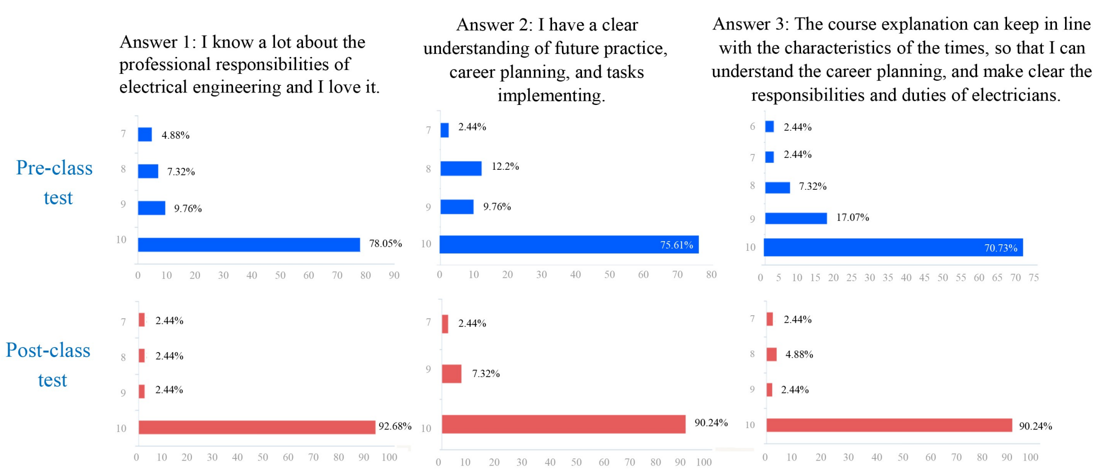

Figure 9 Comparison of social ability evaluations before and after class in the fundamentals of electrical engineering (part 1) course.

evaluate the effectiveness of the knowledge graph-based course design and to identify future directions for improvement. Their feedback could be categorized into objective and subjective aspects.

From an objective standpoint, cultivating learning and development abilities, innovative thinking abilities, and interpersonal adaptability demonstrated significant progress in students' objective ability indicators after implementing knowledge graph technology, indicating positive feedback in this regard.

From a subjective perspective, the voting results in the evaluation process reflected that after the adoption of knowledge graph technology, the students gained a better understanding of the learning contents and interest in the course and electrical engineering as a whole. In other words, the knowledge graph technology sparked students' enthusiasm for learning, and their subjective feedback was positive.

5 Conclusions

Based on the teaching design and practice of specialized courses with a knowledge graph, and taking the fundamentals of electrical engineering course as an example, a ternary graph containing knowledge, issue, and competency layers has been constructed, and the flipped classroom and double closed-loop teaching modes are carefully designed to give full play to students' learning enthusiasm and efficiency. In the practical teaching of the course, students' learning and development abilities have been significantly improved, specifically their cognitive abilities and professional skills. The innovative thinking abilities have been broadened, specifically their divergent thinking ability, associative thinking ability, and critical thinking ability. The interpersonal coordination abilities have been enhanced, specifically their emotion regulation ability, collaboration regulation ability, and situation regulation ability. Finally, social work abilities have been expanded covering three aspects of abilities, including responsibility ability, practical ability, and task ability.

Although the application of knowledge graph technology yielded positive results in a typical electrical engineering course, there are still some areas for improvement and future research. First, this paper focuses only on building a knowledge graph for a single specialized course in electrical engineering. However, knowledge in the electrical engineering field is not distributed solely by individual courses; there are also connections between courses. In the future, consideration could be given to creating joint knowledge graphs across multiple courses. Second, while the knowledge graph for this course is relatively well developed, there are still ongoing efforts to refine and optimize it, such as linking related topics and projects. Future work will further enhance and perfect the knowledge graph for this course.

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Conflict of Interest The authors declare that they have no conflicts of interest.

Ethical Statement Ethical approval was obtained from the Ethics Committee of Wuhan University. In addition, we obtained the participants' permission and consent to participate in this study.

Data Availability Statement The authors confirm that all data generated or analyzed during this study are included in this published article.

References

Bhatia, S. (2018). Sustainable smart universities for smart cities. *Journal of Economics, Management and Trade*, 1–11.

Chen, Y. (2021). Research on data mining of intelligent education evaluation from the perspective of the knowledge graph. *Journal of Physics: Conference Series*, *1955*, 012005.

Guo, C. L., Liu, F. F., & Yang, Y. (2024). Exploration and research on the construction of knowledge graph-enabled curriculum system—Taking signal and information processing courses as an example. *China University Teaching*, (11), 54–60, 87. (in Chinese).

Guo, Y. Z., & Xue, W. (2023). Problems and countermeasures of labor education for college students in the new era. *The Party Building and Ideological Education in Schools*, (16), 48–50. (in Chinese).

Li, H. X., & Liu, X. (2022). Realistic considerations and practical turn of labor education in the digital age. *Inner Mongolia Social Sciences*, *43*(6), 171–177. (in Chinese).

Lin, Q., Zhu, Y., Lu, H., Shi, K., & Niu Z., D (2021). Improving university faculty evaluations via multi-view knowledge graph. *Future Generation Computer Systems*, *117*, 181–192.

Moraes, D. A. P., Pisani, F., & Borin, F. J. (2024). Smart university: A pathway for advancing sustainable development goals. *Internet of Things*, *27*.

Qin, Y. H., Cao, H., & Xue, L. Y. (2020). Research and application of knowledge graph in teaching: Take the database course as an example. *Journal of Physics: Conference Series*, *1607*, 012127.

Ren, S. (2023). Advancing high quality in higher education with digital reform. *China Higher Education*, (2), 47–51. (in Chinese).

Xi, J. P. (2024, February 1). *Xi stresses development of new productive forces, high-quality development*. Available from the State Council of the People's Republic of China website.

Xie, Y. R., Lu, Y., Peng, Z. Y., & Li, C. J. (2024). Inquiry on the integration of "teaching–learning–evaluating" of college courses empowered by knowledge graph. *China Educational Technology*, (12), 1–7. (in Chinese).

Wang, H. J., & Li, Y. (2023). Digital labor education: Innovations, risks, and practices. *Chongqing Higher Education Research*, *11*(2), 43–51. (in Chinese).

Zhang, J. (2025). The limits and paths of digital intelligence enabling high-quality development of education. *Heilongjiang Researches on Higher Education*, *43*(2), 17–22. (in Chinese).

Zhou, L. J., Lv, H. Y., & Liu, K. (2024). Research on curriculum recommendation mode of military vocational education based on near neighbor under construction of knowledge map. *Ordnance Industry Automation*, *43*(11), 47–51. (in Chinese).