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Exploration on Diversified Teaching Mode of Sensor and Detection Technology Driven by Knowledge Graph

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Abstract: This article is based on the goal of cultivating new engineering talents, introduces knowledge graph (KG) technology, constructs the course KG of "Sensor and Detection Technology", and through ontology construction and multimodal resource association, realizes the structuring, visualization, and intelligence of knowledge. Based on this, this paper explores the diversified teaching mode of reconstruction of teaching content, innovation of teaching methods and integration of virtual and real practice teaching. The teaching content breaks the linear logic by relying on the network structure of KG, and supports dynamic updating and personalized path recommendation; The teaching method uses visual navigation and intelligent question answering system to enhance interactivity and inquiry; Practice teaching connects virtual simulation and physical experiment through atlas, realizing the spiral rise of theory and practice. At the same time, a multi-dimensional and dynamic evaluation system covering knowledge mastery, practical ability and innovative thinking is constructed, and intelligent tools are used to realize accurate evaluation and feedback. This model effectively solves the pain points of traditional teaching and provides new ideas and practical reference for improving the teaching quality of engineering courses.

Keywords: Knowledge Graph; Sensors and Detection Technology; Diversified Teaching Mode; New Engineering Course.

1. Introduction

With the in-depth implementation of "Made in China 2025" strategy and the comprehensive promotion of new engineering construction, the deep integration of industrial automation, Internet of Things and artificial intelligence technology puts forward higher requirements for the quality of talent training in colleges and universities [1]. As the core course of electronic information, automation and measurement and control technology, "Sensor and Detection Technology" undertakes the key task of cultivating students' information acquisition and processing ability [2]. This course has the characteristics of abstract concept, complicated principles, involving a wide range of disciplines and strong practicality. It requires students not only to master the working mechanism of various sensors, but also to have the comprehensive ability to design and optimize the detection system for complex engineering scenes.

However, in the long-term teaching practice, the traditional teaching mode of this course has gradually revealed its limitations. First, the knowledge system is fragmented [3]. The existing teaching mostly follows the textbook chapters, and the knowledge points such as resistance, inductance and piezoelectricity are relatively isolated, lacking the explicit logical connection construction, which makes it difficult for students to form a systematic cognitive structure. In the face of comprehensive engineering problems, there is often a dilemma of "seeing only trees but not forests" [4]. Secondly, the teaching methods are simplified. Although multimedia teaching has been popularized, it is still dominated by teachers' one-way indoctrination, lacking attention to students' personalized learning paths, and it is difficult to solve the problems of large differences in students' foundations and differentiation of learning interests. Finally, theory is out of touch with practice. Theoretical teaching and experimental links are often fragmented, so it is difficult for students to map abstract physical principles to specific engineering applications, and the efficiency of knowledge internalization is low [5].

Knowledge graph (KG), as a semantic network that reveals relationships between entities, has shown great potential for application in the field of education in recent years [6]. It can link scattered knowledge points into a network structure through semantic relations, and realize visual display and intelligent reasoning of knowledge. Introducing KG technology into the teaching of "Sensor and Detection Technology" can not only clearly present the context of knowledge, but also realize personalized recommendation of learning path and associated retrieval of knowledge points based on data mining technology, which provides a new technical path to solve the above teaching pain points [7].

Based on this, based on the training goal of new engineering talents, this paper constructs the course KG of "Sensor and Detection Technology", and takes this as the driving force to explore the diversified teaching mode of teaching content reorganization, teaching method innovation and evaluation system reconstruction. It aims to break the time and space limitations of traditional classroom through technical empowerment, realize the organic unity of knowledge imparting and ability training, and provide new ideas and practical reference for improving the teaching quality of engineering courses.

2. KG construction of "Sensor and Detection Technology" course

2.1. Knowledge Ontology Construction

The construction of knowledge ontology is the foundation of course KG construction, which aims to precisely define the core concepts, attributes and logical relationships between concepts of the course and build a solid skeleton for the whole KG.

(1) Sorting out the core concept system

In-depth analysis of "Sensor and Detection Technology" course content, comprehensively combing the key concepts covering the core sectors such as sensor principle, detection technology, signal processing and system application. For example, at the sensor principle level, the core concepts of various sensors, such as resistive, capacitive, inductive and photoelectric, are defined; In terms of detection technology and methods, the concepts of static detection, dynamic detection and nondestructive detection are defined. Through rigorous combing work, a clear-cut and comprehensive core concept system is constructed to ensure that there is no omission or overlap in curriculum knowledge and lay a solid foundation for subsequent knowledge organization.

(2) Precise definition of conceptual attributes

We give each core concept an accurate and complete attribute description, showing the essential characteristics and key information of the concept in all directions. Taking the resistive sensor as an example, its properties include working principle, structural composition, sensitivity, linearity, measuring range, applicable scenarios and so on. These attributes not only clearly define the boundaries of concepts, but also provide rich data support for subsequent knowledge retrieval, reasoning and application, enabling students to deeply understand concepts from multiple dimensions and enhance their mastery of knowledge.

(3) Conceptual relationships are clearly defined

Dig deep into the internal logical relationship between core concepts, and clearly construct diversified semantic relationships such as hyponymy, causality, composition, application scenario association [8]. For example, resistive sensor and capacitive sensor belong to the upper concept of juxtaposition, while the strain gauge in resistive sensor is its lower concept, which embodies the composition relationship; There is a causal relationship between sensor sensitivity and measurement accuracy, and different sensor types are associated with specific detection scenarios. By clearly defining these relationships, a closely connected and logically self-consistent conceptual network is constructed to help students grasp the context of knowledge and realize the migration and expansion of knowledge.

2.2. Multimodal Resource Association

Multi-modal resource association is an important expansion of course KG construction, which breaks the limitation of single-modal resources, deeply integrates various resources such as text, image, audio, video and experimental data with knowledge ontology, and forms a rich, diverse and interactive knowledge presentation system to meet the learning needs of different students and enhance the learning experience [9].

(1) Accurate mapping between resources and knowledge ontology

For each kind of multimodal resources, according to its content theme and core knowledge points, an accurate mapping relationship with knowledge ontology is established. For text resources, such as textbook chapters, academic papers, technical documents, etc., they are closely related to the corresponding knowledge nodes such as concepts, principles and methods, so as to realize the seamless connection between text content and KG; For image resources, such as sensor structure schematic diagram, detection system schematic diagram, etc., mark their corresponding knowledge concepts, so that images become a powerful carrier of knowledge visualization; For audio resources, such as expert explanation recording and technical lecture audio, key information is extracted and bound with relevant knowledge points to facilitate students to acquire knowledge anytime and anywhere; For video resources, such as sensor experimental operation video, detection technology application case video, etc., through video content analysis and knowledge annotation, video clips are associated with knowledge ontology, so that students can intuitively understand knowledge during watching videos; For experimental data resources, such as sensor performance test data, test result data, etc., it is associated with the corresponding knowledge nodes such as sensor principle, detection technology and methods, which provides practical data support for students and deepens their understanding and application of knowledge.

(2) Multi-modal resource fusion and interactive design

On the basis of realizing the accurate mapping between resources and knowledge ontology, we pay attention to the integration and interaction design between multimodal resources [10]. Build a unified resource display platform, organically integrate multi-modal resources such as text, image, audio, video and experimental data, and present knowledge content in a complementary and collaborative way. When learning the working principle of the sensor, the text explanation, structural schematic diagram, animation demonstration video and experimental operation video are simultaneously displayed, so that students can fully understand the knowledge from the perspectives of text description, graphic display, dynamic demonstration and practical operation. At the same time, interactive functions are designed, such as clicking on the image to view the relevant text descriptions, playing the video to simultaneously display the subtitles of key knowledge points, and students can freely switch different modal resources according to their learning needs to realize personalized learning. In addition, by setting up interactive links, students can interact deeply with KG and multimodal resources, and their learning interest and initiative can be stimulated.

(3) Dynamic renewal and optimization of resources

Establish a dynamic updating and optimization mechanism of multimodal resources to ensure the timeliness and advancement of KG. With the rapid development of Sensor and Detection Technology, new technical data, research results, application cases, etc. are collected and sorted in time, which are transformed into multimodal resources and incorporated into KG, and the relationship between knowledge ontology and resources is updated. According to students' learning feedback, teaching effect evaluation and technology development trend, the existing multimodal resources are optimized and adjusted to improve resource quality and learning effect. Through continuous dynamic updating and optimization, the course KG keeps fresh vitality all the time, provides students with the latest and best learning resources, and helps to cultivate high-quality talents to meet the needs of the development of the times.

2.3. Selection of Technical Tools and Platforms

Using Protégé platform to model knowledge ontology, and using its visual editing interface to define the core concepts, attributes and relationships of the course; Combined with Python's OWLReady2 library, it realizes the automatic analysis and expansion of ontology, and supports the knowledge representation and reasoning in RDF/OWL standard format. The secondary Neo4j graph database is selected as the storage and query engine of KG, and the efficient retrieval and association analysis of knowledge nodes are realized by Cypher language. The front-end visualization uses D3.js or ECharts library to build an interactive knowledge network map, which supports dynamic scaling, path tracing and multi-dimensional filtering. Pandas and Scikit-learn library based on Python realize feature extraction and semantic matching of multimodal resources; Using OpenCV and Librosa to process the metadata annotation of image and audio resources respectively; Video slicing and key frame extraction are carried out by FFmpeg, and entity recognition and knowledge mapping of text resources are realized by combining with NLP toolkit. Build a KG service interface based on Django or Flask framework to realize seamless connection with the teaching platform; Docker containerized deployment is adopted to ensure the scalability and stability of the system.

3. Design of Diversified Teaching Mode based on KG

Taking KG as the core technology engine, this study aims to reconstruct the course teaching system of Sensor and Detection Technology, which has strong cross-cutting, complicated knowledge points and diverse application scenarios. By constructing domain KG, the structure, visualization and intelligence of teaching content are realized, and on this basis, the deep integration and innovation of teaching content, method and practice are driven. The specific design is shown in Figure 1 below.

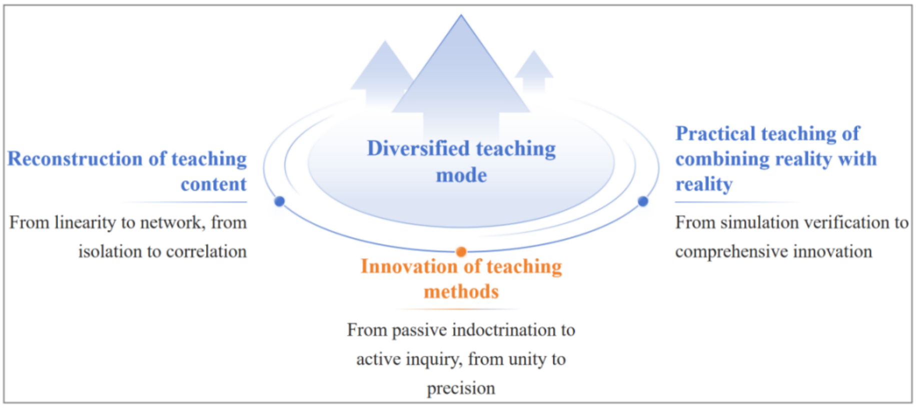

Figure 1. Design framework of diversified teaching mode based on KG

The core of this model design is to upgrade "KG" from a static knowledge base to an "intelligent hub" that drives the whole teaching process. It reshapes the organizational logic of teaching content, empowers diversified teaching methods, and opens the practical link from virtual cognition to entity innovation, with the ultimate goal of cultivating innovative talents who can think systematically, explore independently and solve complex engineering problems.

3.1. Reconstruction of Teaching Content

Traditional teaching content is often developed linearly according to chapters, and the links between knowledge points and between theory and practice are easily separated. KG-based reconstruction aims to break this limitation. First of all, the system combs the core knowledge elements such as sensor principle (physical/chemical effect), sensor type (resistance, capacitance, inductance, photoelectricity, etc.), detection circuit (signal conditioning and conversion), and typical applications (industrial control, environmental monitoring, medical health). Using KG technology, these knowledge points are regarded as "nodes" and their logical relationship as "edges", and a domain KG with clear hierarchy and clear relationship is constructed. This makes the curriculum knowledge system change from a book catalogue to a visual knowledge network.

The network structure of KG supports nonlinear teaching path design [11]. Teachers can intelligently recommend or manually plan different learning paths (learning subgraphs) according to their major focus or student foundation. For example, for the major of Internet of Things, we can strengthen the learning of the related path of "sensor-signal-wireless transmission-cloud application". As a "living" structure, KG can be easily integrated into the latest sensor technology, detection standards and emerging application cases as new nodes and relationships, so that the teaching content can keep up with the technological development and realize dynamic updating.

3.2. Innovation of Teaching Methods

Using KG's visualization and associative reasoning ability, the fundamental change of teaching methods is driven. In the course of teaching, the visual interface of KG is directly used for navigation and explanation. Teachers can intuitively expand their derivative sensors (piezoelectric sensors), related measuring circuits (charge amplifiers) and typical applications (vibration measurement and ultrasonic probe) from any core concept, so that the abstract and complex principles become concrete and vivid. Students can intuitively grasp the overall context and internal relations of knowledge.

Based on the constructed KG, an intelligent question answering system is developed. Students can enter "How to choose a sensor to measure the temperature range?" Or "what are the similarities and differences between photoelectric encoder and Hall sensor in speed measurement?" And other complex problems, the system can give structured answers or recommend related learning resources according to the associated paths in KG. At the same time, the system can diagnose the weak points of students' knowledge (broken or incomprehensible nodes in KG) according to their practice feedback, and push targeted learning materials and remedial exercises.

Extend teaching activities to the process of building and perfecting KG itself. Design group tasks, so that students can collect and sort out relevant Sensor and Detection Technology knowledge around a specific application scenario, and submit it in a structured form, which will be integrated into the course KG after being reviewed by teachers. This can not only deepen students' understanding of knowledge, but also cultivate their ability of information integration and knowledge modeling.

3.3. Practical Teaching of Virtual–Real Integration

Taking KG as the "brain" and "navigation map" connecting virtual simulation and physical practice, a practical teaching system with hierarchical progression and virtual reality blending is constructed. In the virtual simulation experimental platform, KG interface is integrated. When students carry out the simulation of "Bridge Design and Debugging of Pressure Sensor", the system can automatically correlate and prompt related knowledge nodes in KG. In the face of a comprehensive testing task, students can use KG for scheme planning. According to the detection parameters (temperature, humidity, illumination, soil pH), KG can recommend a variety of feasible sensor selection combinations, signal conditioning schemes and communication modes, and associate the existing virtual simulation cases with the list of physical experimental equipment to help students complete the leap from principle to scheme. Practice teaching follows the path of "KG cognition → virtual simulation verification → entity practice innovation". Students first understand the composition and principle of the system on KG, then complete the scheme design and debugging in the virtual environment at low cost and without risk, and finally build a real system and solve practical problems in the physical laboratory by using the equipment and methods recommended by KG. KG runs through, ensuring the seamless connection and spiral rise of theory and practice.

In order to verify the effectiveness of KG-driven practical teaching, this study takes "Design of Intelligent Greenhouse Environment Monitoring System" as a typical practical case and carries out a 16-week teaching experiment. The experimental class (n=48) adopts the KG-driven teaching mode, while the control class (n=45) adopts the traditional teaching mode. There is no significant difference in the academic level of the two groups (p>0.05).

Operating steps:

1. KG cognitive stage (2 hours). Through the visual interface of course KG, students in the experimental class systematically sort out the sensor selection of temperature, humidity, light, soil pH value and other parameters, and understand the working principle, performance parameters and applicable scene correlation of various sensors (DS18B20, DHT11, BH1750, soil pH electrode). The control class is taught by traditional PPT.

2. Virtual simulation verification stage (6 hours). In the Proteus simulation platform, the experimental class uses the signal conditioning circuit (bridge circuit, amplification and filtering module) and communication scheme (ZigBee/WiFi) recommended by KG to complete the system hardware construction and program debugging, and KG associates fault diagnosis nodes in real time to assist in debugging. The control class was operated according to the fixed experimental instruction.

Table 1. Comparison between traditional teaching and KG-driven teaching

Evaluation dimension	Index	Traditional teaching class (n=45)	KG-driven class (n=48)	Promotion rate
Theoretical knowledge	Final average score	72.3±8.5	85.6±6.2	+18.4%
	Pass rate (≥60 points)	75.6%	93.8%	+18.2%
	Excellent rate (≥90 points)	11.1%	31.3%	+20.2%
Practical ability	Normative score of experimental operation	68.4±9.2	88.2±5.7	+29.0%
	Fault diagnosis ability score	62.1±10.5	84.5±6.8	+36.1%
	System design integrity score	58.3±11.4	82.1±7.3	+40.8%
	Experimental report quality score	70.5±8.8	86.4±5.9	+22.6%
Comprehensive quality	Course satisfaction (5 points)	3.3±0.8	4.6±0.5	+39.4%
	Self-assessment of autonomous learning ability	2.8±0.9	4.2±0.6	+50.0%
	Innovation proposal rate	18.2%	56.3%	+38.1%

3. Entity practice innovation stage (8 hours). According to the equipment list (STM32 development board, sensor module, OLED display screen) and wiring scheme recommended by KG, the experimental class built a real system in the laboratory, and calibrated and optimized the parameters for the actual greenhouse scene. The control class completed the basic confirmatory experiment.

The success rate of system debugging in the experimental class reached 91.7%, which was 22.8 percentage points higher than that in the control class (68.9%). The average troubleshooting time was shortened to 12.5 minutes (28.3 minutes in the control class); The adoption rate of innovative schemes (such as adding wireless transmission and cloud monitoring functions) reached 56.3% (18.2% in the control class).

After-class questionnaire shows that the students in the experimental class are significantly better than those in the control class in terms of "knowledge relevance clarity" (4.6/5 vs 3.1/5), "confidence in experimental operation" (4.4/5 vs 3.2/5) and "self-evaluation of engineering problem solving ability" (4.2/5 vs 2.9/5) ($p<0.01$). Typical feedback such as: "KG let me know clearly the basis and related knowledge of each sensor selection, and I will not blindly try and make mistakes" (student A); "Intelligent hints in virtual simulation are very helpful, just like a teacher guiding at any time" (student B).

After a semester's teaching practice, the theoretical achievements, practical ability and comprehensive quality of the students in the two classes are comprehensively compared, and the results are shown in Table 1.

The average score of KG-driven classes is 85.6, which is 18.4% higher than that of traditional classes (72.3). The passing rate increased from 75.6% to 93.8%, and the excellent rate increased from 11.1% to 31.3%, indicating that KG visual navigation and intelligent question answering system effectively promoted the internalization and systematic construction of knowledge.

KG-driven teaching is significantly superior to traditional teaching in terms of experimental operation standardization (88.2 vs 68.4), fault diagnosis ability (84.5 vs 62.1) and system design ability (82.1 vs 58.3), among which the system design ability is improved most significantly (+40.8%), which proves that "KG cognition → virtual simulation → entity practice"

The average time spent by KG-driven classes in various experiments is 29%-35% shorter than that of traditional classes, and the time spent in strain gauge pressure detection experiments is reduced from 65 minutes to 42 minutes (the efficiency is improved by 35%), which shows that KG-assisted experimental navigation and fault prompt have significantly improved the learning efficiency.

KG-driven teaching is significantly superior to traditional teaching in subjective indicators such as course satisfaction (4.6 vs 3.3), interest in learning (4.5 vs 3.2) and confidence in problem solving (4.4 vs 3.1), and the self-evaluation of students' autonomous learning ability is improved by 50%, which reflects that KG-driven inquiry learning effectively stimulates learning motivation and initiative.

4. Construction of Diversified Evaluation System

4.1. Multi-dimensional Evaluation Index Design

The construction of diversified evaluation system is an indispensable part. This system can comprehensively and objectively evaluate students' learning effectiveness and promote their all-round development of knowledge, skills and quality. The specific design idea of multi-dimensional evaluation index is shown in Figure 2 below.

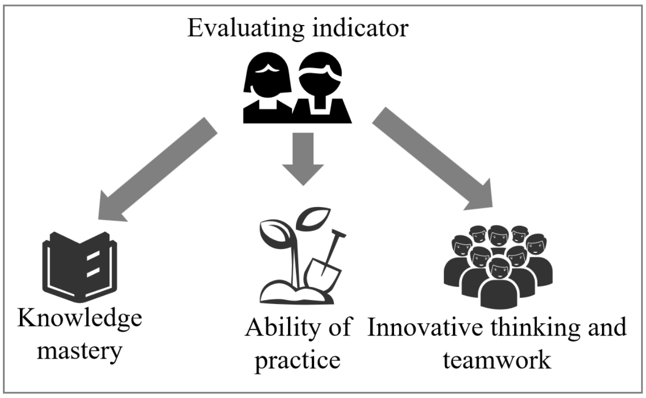

Figure 2. Multi-dimensional evaluation index design

(1) Knowledge mastery

Through online test, chapter test and mid-term and final exam, students' mastery of core knowledge such as sensor principle, detection technology, signal processing and system application is evaluated. Using KG's associative reasoning ability, we designed a test question containing hierarchical progressive questions to test whether students have formed a systematic knowledge structure.

(2) Practical ability

Through virtual simulation experiments and physical experiments, students' practical ability and problem-solving ability are evaluated. Experimental report, project design and system debugging records can be used as evaluation basis. At the same time, using the design and optimization of KG-aided experimental scheme, the students' ability to apply theoretical knowledge to practical engineering scenes was investigated.

(3) Innovative thinking and teamwork

Evaluate students' innovative thinking, teamwork ability and information integration ability through group projects, innovation competitions and other forms. Project report, team presentation, peer review and other links can fully reflect the comprehensive quality of students. Encourage students to independently collect and organize relevant knowledge around specific application scenarios, and submit it in a structured form, which will be integrated into the course KG after being audited by teachers, so as to cultivate students' knowledge modeling ability.

4.2. Dynamic Evaluation Process

In the teaching process, formative evaluation is implemented, and students' learning progress and difficulties are timely understood through classroom interaction, online discussion and group work, so as to provide personalized feedback and guidance. At the end of the course, make a summary evaluation to comprehensively evaluate the students' learning effectiveness. Establish students' learning files and record their performances in the learning process, including test scores, experimental reports, project results, etc. Through data analysis technology, students' learning rules and potential problems are excavated to provide basis for teaching improvement. At the same time, according to students' learning feedback and teaching effect evaluation, the evaluation standards and methods are dynamically adjusted to ensure the scientificity and effectiveness of the evaluation system.

4.3. Application of Intelligent Evaluation Tool

Using KG to build an intelligent question answering system, students can get structured answers or related learning resources by inputting questions. The system can also diagnose the weak points of students' knowledge according to their practice feedback, and push targeted learning materials and remedial exercises. This function not only helps students to learn independently, but also provides accurate teaching feedback for teachers. Build a learning analysis platform to integrate students' learning data, interactive records, test scores and other multi-source information. Through data mining and machine learning technology, this paper analyzes students' learning behavior patterns, knowledge mastery and development potential, and provides data support for personalized teaching. At the same time, the learning analysis platform can also provide scientific basis for the continuous optimization of diversified evaluation system.

5. Conclusion

KG organically connects scattered knowledge points through semantic network, which effectively solves the problems of knowledge fragmentation, single teaching method and disconnection between theory and practice in traditional teaching. In the innovation of teaching mode, based on KG's visual navigation and associative reasoning ability, teachers can flexibly design nonlinear teaching paths, and students can get personalized learning support through intelligent question-and-answer system. At the same time, the practice system of combining reality with reality opens up the cognitive closed loop from virtual simulation to entity experiment, which significantly improves students' engineering practice and innovation ability. In addition, the deep integration and dynamic updating mechanism of multi-modal resources not only enriches the presentation form of teaching resources, but also ensures the cutting-edge and adaptability of course content. Through data mining and machine learning technology, the multi-dimensional evaluation system realizes the accurate evaluation of students' knowledge mastery, practical ability and innovative thinking, and provides a scientific basis for personalized teaching. In the future, it is necessary to further explore the deep coupling between KG and artificial intelligence technology, and continuously optimize the teaching ecology of man-machine collaboration to meet the rapidly evolving industrial technology needs.

Acknowledgments

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