Opening Knowledge Graph Model Building of Artificial Intelligence Curriculum

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Abstract—The knowledge points setting of artificial intelligence curriculum has shortcomings in connection between theory and practices. To overcome the problem, this study designs an open knowledge point design model based on knowledge graph. Fist, to promote the construction of the knowledge graph (KG) of curriculums, associated teaching research was analyzed visually. Then the order and hierarchical structure of the knowledge points were defined, and the ontology structure of curriculum knowledge and the relationship between knowledge points and posts were designed as well. Moreover, an overall logic structure for the construction of the open KG of curriculums was proposed. Results demonstrated that high attention should be paid to the construction and concern of teaching teams for artificial intelligence algorithms and the KG of curriculum construction. Additionally, the opening model can strengthen the openness of the KG of curriculums to reinforce the close connections between classroom knowledge and practices. Research conclusions are conducive to understand the existing problems in the KG of curriculums and provide beneficial references to the integration of information technology and education.

Keywords—artificial intelligence, KG of curriculums, university education, educational informationization

1 Introduction

With the development of cloud computing and big data, online education has changed the traditional teaching mode. Various mainstream education platforms worldwide have launched abundant learning resources in different forms, such as text, audio, video. Online course learning has become one of the most common learning modes. Students, life-long learners, and adult education learners can all use fragmented time and acquire considerable learning resources according to their learning demands.

At present, building educational informationization based on the new generation of information technology has become the essential trend. Among them, the knowledge graph (KG) is attracting increasing attention [1]. According to application fields, KG usually is divided into two types: the general-purpose knowledge graph (GKG) and the domain-specific knowledge graph (DKG). For the GKG, many scholars have carried out deep studies on key technologies related to the construction and learning of KG, knowledge evolution, and reasoning. The multi-element, multisubject, and multidata-source KG construction has achieved rapid development [2].

In university education, artificial intelligence as an important major is characteristic of diversified information, diversified learning modes, and diversified curriculums, which also bring many problems. (1) With respect to the training mode, students accept different programming requirements for different curriculums. The construction of most teaching teams lacks a uniform management mode, and students are tired of the follow-up use of programming platforms and tools. (2) The artificial intelligence curriculum involves a lot of teaching content, and complicated relations exist among knowledge points. Textbooks contents emphasize the introduction of basic concepts, classical algorithms, and applications, which are boring and disconnected from practical applications at present. All of these problems are barriers against the development of university education even though the education resource development of universities and colleges are of substantial concern among education researchers and users.

For both traditional education and new education based on information technology, education itself is a data-intensive industry. The essence of KG is to connect things and concepts through interactions [3,4]. This characteristic implies that the curriculums of artificial intelligence in university education can reconstruct connections among knowledge from abundant disordered information resources based on KG and a knowledge system of different curriculums can be established effectively.

Therefore, analysis and research on curriculum knowledge of artificial intelligence and building of KG for the curriculums are significant to the knowledge acquisition and curriculum learning of learners. Notably, the KG of curriculums in the present study belongs to DKG. The follow-up state of the art is carried out on the basis of the KG of curriculums.

2 State of the art

KG was first used for searching. In 2012, Google launched the KG project and announced the construction of a next-generation intelligent search engine based on KG [5]. KG has promoted the development of a semantic network since it was proposed in 2012. Many giant scientific and technological companies have applied KG to support the development of intelligent applications [6]. With respect to education, many scholars have studied how to use KG in classroom teaching, online teaching, and higher education.

Most academic studies on the KG of curriculums focus on the following aspects. First, research hotspots and leading edges have been analyzed using KG. Shao et al. [7] discussed and analyzed research hotspots in the field of recommendation systems and corresponding characteristics. Meanwhile, Mu et al. [8] analyzed research development on mechanical engineering practice teaching and discussed current research hotspots as well as existing problems. In addition, Liu et al. [9] helped postgraduates to understand quickly the professional subjects in which they were interested on the basis of KG, thus improving the scientific research level of postgraduates.

Second, network relations among subject knowledge points were established using KG tools. Seo et al. [10] proposed how to provide learning paths for learners. Furthermore, Karas et al. [11] proposed a method to help students to form the knowledge network model and analysis of KG. In another study, Alshalabi et al. [12] proposed an adaptive learning path algorithm by analyzing the structure of domain-specific knowledge to improve the academic performance of students. Moreover, Lv et al. [13] solved the lack of logic knowledge relations on the semantic level using the nursing KG of the curriculum model. Chen et al. [14] proposed the knowledge mapping system in the education field to extract the relationship between teaching concepts and implicit education from heterogeneous data sources.

Third, some scholars have explored the recommendation of education resources on the basis of KG. In particular, KG-based recommendation system focus on education resources or relevant academic contents, which can be integrated into the learning process in [15,16].

Existing studies on network relations among knowledge points in the education field mainly focus on KG among different subjects. This type of KG generally has problems on single nodes, single relations, and single attributes, as well as the coarse division granularity of knowledge points. Nevertheless, the KG of curriculums is more important to students in practical teaching processes. Students can have supplemental learning by searching for knowledge points or basic knowledge points similar to the current knowledge points according to KG. They can also search for the next knowledge point for learning according to KG once a knowledge point has been mastered. In other words, the existing DKG models generally have insufficient generalization ability and poor ability. Some scholars have also studied the KG of specific curriculums thoroughly and developed many KG cases of curriculums [17,18].

With the scientific technological development, theories and technologies of KG are becoming increasingly perfect and mature, and its application ranges are expanding gradually [19]. To master the application status of the KG of curriculums in teaching accurately, studies about the KG of curriculums have been summarized comprehensively and systematically through bibliometrics and information visualization. The studies are expected to show research hotspots and trends intuitively. Subsequently, the design framework of the open KG of curriculums is proposed. This framework is of importance to teaching design based on KG and training application-oriented innovative talents in China.

The reminder of this study is organized as follows. Section 3 analyzes and discusses studies concerning the KG of curriculums. Then, Section 4 proposes the design framework of the open KG of curriculums. Finally, Section 5 summarizes the conclusions.

3 Methodology

3.1 Data source

Data from January 2013 to December 2021 were collected from the Chinese National Knowledge Infrastructure (CNKI). Studies in the journal were searched using the keyword "knowledge graph of curriculums". Irrelevant studies were excluded by reading the abstracts manually, and a total of 168 studies were searched. Finally, the data were output in EndNote using the format of CNKI and were stored as preparation for the next studies. Subsequently, quantitative statistics and analyses on the number of studies published, keywords, and other characteristics were carried out using SPSS Statistics and UCINET analytical tools.

3.2 Comparison and analysis

Time zone and theme distribution of articles. The quantitative distribution of annual literature studies can reflect the state of the art and the overall outcomes of the field to some extent. To make data more intuitive, a statistical analysis on relevant studies published from January 2013 to December 2021 was carried out, through which the tendency chart of the quantity of the annual academic literature was obtained (Figure 1). In Figure 1, the red and blue tendency lines represent the annual distributions gained by using "knowledge graph of curriculums" and "knowledge graph" as keywords, respectively. Evidently, KG has extensive applications in other fields, but it is relatively rarely used in classroom education. Studies on the KG of curriculums in universities and colleges in China started in 2013, and an extremely small quantity of studies have been published in this field. However, the trend of curves shows that researchers are becoming increasingly interested in the applications of KG in teaching fields, and the relevant literature is growing quickly.

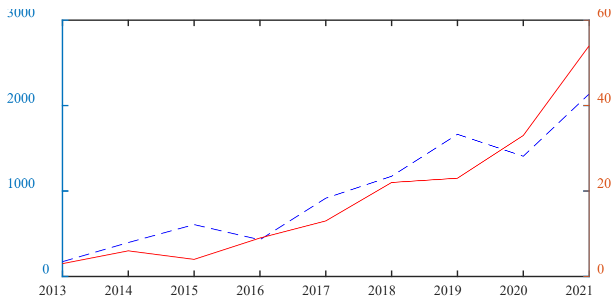

Fig. 1. Annual distribution of academic literatures related to KG

Subsequently, theme distributions related to the KG of curriculums were analyzed in this study. The results are shown in Figure 2. Clearly, themes that are mostly related to the research contents of this study can be summarized as knowledge graph analysis, visual analysis, knowledge graph construction, and curriculum development. All of these themes can reflect the state of the art intuitively. Notably, studies related to curriculum development account for 2.96%. This amount also indicates that although KG has attracted some attention and achieved some development in the field of education, few curriculum-based KG cases are available.

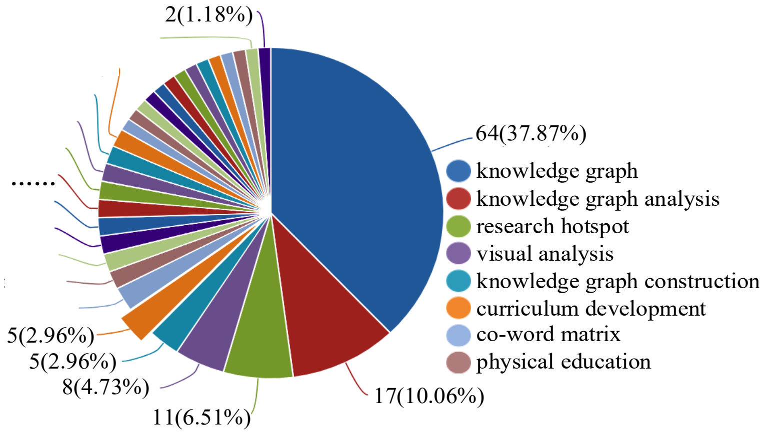

Fig. 2. Research theme distribution of literature related to KG of curriculums

Literature publishing conditions of authors. The co-occurrence network graph of authors can reflect the cooperative relations of authors in this area of research. Figure 3 demonstrates that teaching researcher groups are scattered and the number of published studies is not concentrated. The cooperative relation among different research teams is relatively weak. The Table 1 shows that F. Sun from Wenzhou University published the most articles (four articles) in the education field, while most authors published less than two articles. During the literature review, most research teams were composed of members from the same institution as the author, and the cooperation among institutions is relatively weak. On one hand, the above situations demonstrate that many scholars engage in the KG-related education field and take the initiative to explore teaching reforms. On the other hand, the circumstances also prove that no core author group has been formed. Moreover, most authors lack continuous concern of the KG-related education field.

Table 1. Relevant information of authors with high publications

Sorting	Author	Num. (papers)	Subordinate institution
1	F. Sun	4	Wenzhou Univ.
2	L. Pan	3	Wenzhou Univ.
3	P. Cheng	2	Chongqing Univ. of Tech
3	H. Peng	2	Wuhan Univ. of Tech
3	G. Zhang	2	Wuhan Univ. of Tech

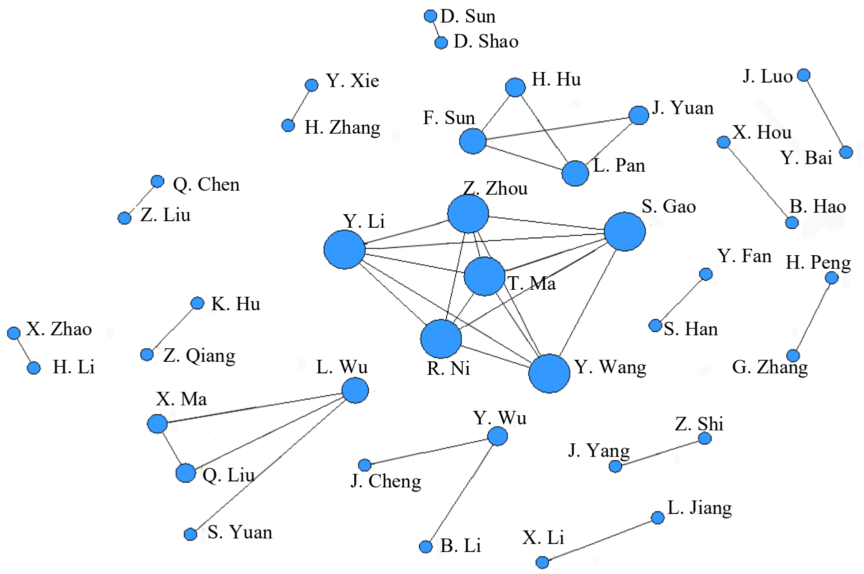

Fig. 3. Co-occurrence network graph of authors

Research hotspot analysis based on keywords. Research hotspots refer to research problems or subjects discussed by a group of papers that have internal connections and a high quantity within a period. Keyword refers to the high extraction and summary of the author to core contents. It reflects the core contents and important information of a study. Hence, keywords that occur frequently can be used to determine hotspots in a research field.

The keyword co-occurrence network can reflect the research hotspot and development trend of a field. In this study, the keywords used in studies were analyzed using SPSS Statistics. Overall, 496 keywords were collected. Among them, high-frequency keywords were screened and used to construct the co-occurrence matrix of keywords. This co-occurrence matrix can reveal internal connections among keywords. The formula of transformation into the similar matrix is:

$$S_{ik} = \frac{N_{ik}}{(N_i * N_k)^{1/2}} \tag{1}$$

Where N_{ik} is the co-occurrence frequency of two keywords, is the occurrence frequency of the keyword i, and N_k is the occurrence frequency of the keyword k. According to the formula, the co-occurrence matrix can be constructed according to this formula. If the number is closer to 1, the two keywords are more similar; otherwise, the two keywords are less similar.

To discover important information in the data and explore internal connections of hotspots in the KG-related education field, the extracted co-occurrence matrix was input into the UCINET software, and the co-occurrence graph of keywords was plotted (Figure 4). Figure 4 demonstrates that keywords, such as "flipped classroom","visual analysis","personalized learning","learning path","online course" and "MOOC" were all surrounding "KG".Moreover, they had a short relative distance with "KG". This observation proves that the nodes where these keywords were located were closely related. In contrast, keywords like "core literacy", "artificial intelligence" and "curriculum reform" were at edges of the co-occurrence graph, thus indicating that they might be research hotspots in future.

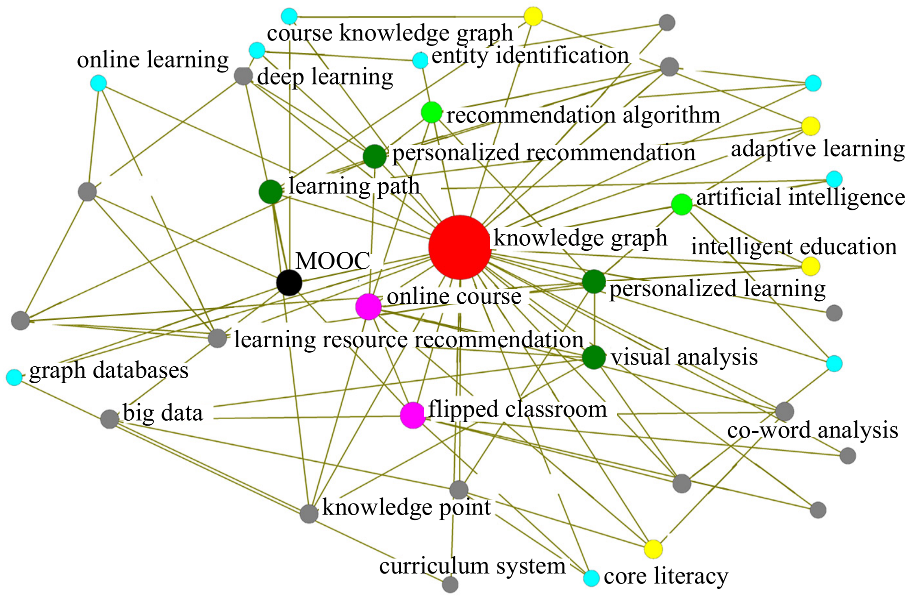

Fig. 4. Co-occurrence network graph of keywords with high frequency

Clustering analysis of high-frequency keywords. For the convenience of exhibition, the top 18 high-frequency keywords were clustered in the co-occurrence matrix. After the type (pedigree), method (intergroup connection), and measurement standard interval (square Euclidean distance) of the graph were set, the keywords clustering graph is shown in Figure 5. The figure shows that these two keywords were divided into two clusters. According to the meaning of keywords in each cluster, the tag of each cluster was defined as "Cluster#1:individualized education" and "Cluster#2:curriculum development". Cluster#1 mainly reflected the applications of various artificial intelligence algorithms in personalized learning, path recommendation, and logic reasoning. Cluster#2 mainly reflected how to construct the KG of curriculums by using existing curriculum standards, disciplinary knowledge, and teaching resources. Both clusters reflected two research directions of KG in China.

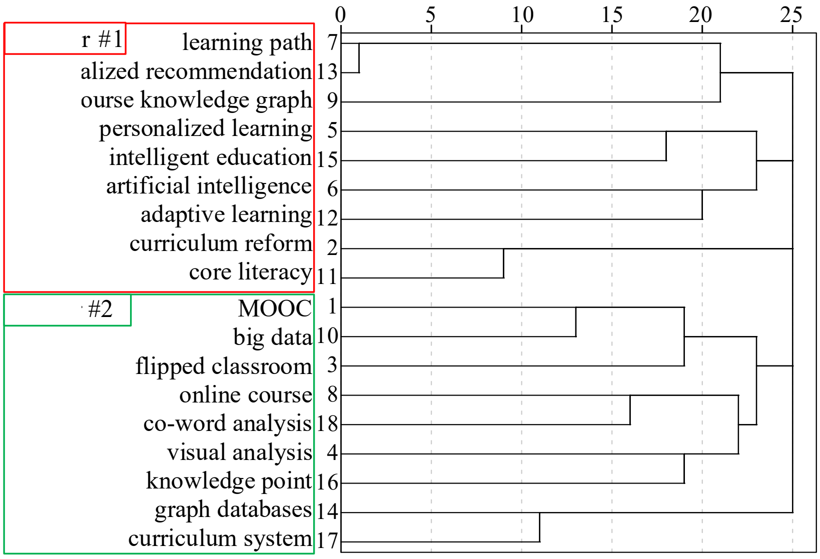

Fig. 5. Clustering results of keywords

According to the previous statistical analysis, some problems are summarized as follows. (1) KG construction of curriculums is still in an exploration stage because the KG of curriculums belongs to DKG. On one hand, the construction of DKG requires professional field knowledge. On the other hand, the data source in the professional field has a small size, and it cannot meet the needs of the data size. (2) The KG construction of curriculums is closed. Such closeness not only means that few teaching teams are cooperating with other institutions, but it also entails teaching knowledge points and delayed market demands in the setting. Upon reading the literature, the author also found that the KG construction of curriculums has a low quality at present. For example, the teaching objective, teaching design, and teaching mode are limited within institutions to which teachers are affiliated, professional student groups they face during daily teaching, and the accumulated teaching experiences of teachers or teaching teams.

In this study, the first problem that the KG of curriculums faces will be solved in time. In the following text, how to design an open KG of curriculums will be discussed.

4 Result analysis of open KG design of curriculums

How to construct an open KG is discussed through a case study of artificial intelligence in university education. Artificial intelligence has been selected as an example mainly because it is an integrated discipline with highly disciplinary crossing and integration involving machine learning, pattern recognition, data mining, and neural network. Moreover, artificial intelligence has been applied extensively [20]. Although many universities and colleges have carried out a teaching reform for artificial intelligence in recent years, they still have shortcomings in connecting theory with practice [21].

To solve these problems, the training scheme and curriculum content have been formulated together with enterprise engineers according to the post requirements, thus finishing the KG design. Teachers and engineers cooperate in setting the overall logic structure for an open KG (Figure 6). (1) Clearly, teachers use teaching resources, CNKI, and Baidu as major data sources. After the semantic analysis of the resource description library based on semantic analysis tools, keywords were extracted, and the semantic description model and KG based on structures were constructed. (2) Meanwhile, enterprise engineers mainly use the occupational ability of artificial intelligence posts as the major data source. Combining with knowledge points setting by curriculum teachers, network key nodes were built through semantic tools for semantic description, and an industrial KG based on professional skills was built.

As KG is a structured semantic knowledge library, the ontological structural design of the KG of curriculums is the key link. In the following text, the curriculum resource ontological model design was taken as an example to elaborate how teachers and engineers construct KG (Figure 7). The KG of curriculums is an important reference to select the learning content and recommend a learning path. According to the requirements of enterprise engineers for occupational ability, the knowledge points that the curriculum required were analyzed. To assure that learners could choose learning contents within the controllable range, the KG of curriculums used chapter, section, and knowledge points as knowledge units and involved three semantic relations: "inclusion relation", "fore-and-aft relation" and "parallel relation" [17]. In this study, the curriculum knowledge structural model defines the order and hierarchical relations of knowledge points [18].

Definition 1: Knowledge point (K_e) model: This knowledge point cannot be cut into other knowledge points, that is, the lowest semantic level.

Definition 2: Knowledge chain (K_c) model: It is the superior layer of the knowledge point. The knowledge chain is the chain structure formed by knowledge points according to different logic relations (Eq.(2)):

$$K_c = < (K_{ei}, K_{ek}), R > \quad (2)$$

where K_{ei} and K_{ek} are different knowledge points. R refers to the relationship among knowledge points, which are divided into order relations and hierarchical relationship.

Definition 3: Knowledge unit (K_u): It is the superior layer of the knowledge chain, and it is formed by knowledge chains (Eq. (3)).

$$K_u = (K_{ci} | i = 1, 2, ..., N) \quad (3)$$

Definition 4: Course knowledge entity model (CKEM, K_{ckem}): It is the superior layer of a knowledge unit, and it is formed by different knowledge units (Eq. (4)).

$$K_{ckem} = (K_{ui} | i = 1, 2, ..., N) \quad (4)$$

In this study, learning contents in the curriculum form the CKEM according to "knowledge points, knowledge chains, knowledge units." When the ontology model of the curriculum is determined, the hierarchical system of the curriculum ontology can be acquired using the Protégé tool to define the conceptual attributes and data attributes. The final model (e.g., type, example, relation and attributes) is stored in RDF format, and it is input into the graph database Neo4j. As this study focuses on the state of the art and proposes solutions to existing problems in the KG of curriculums, it has not introduced methods to establish KG for a curriculum.

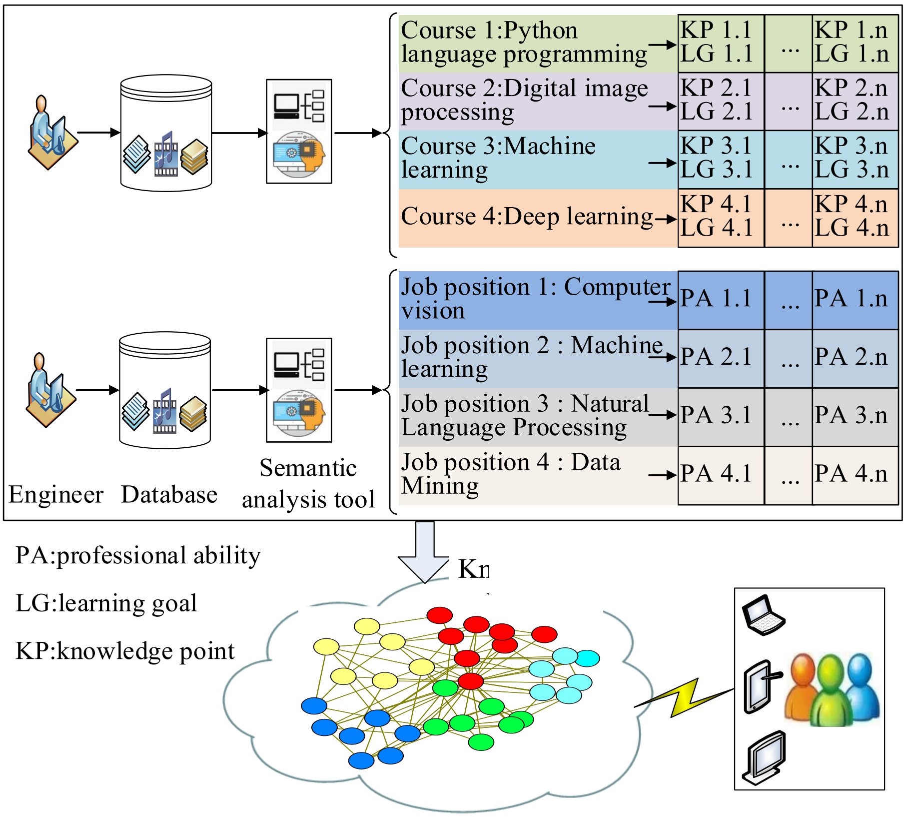

Fig. 6. Overall logic structure of open KG

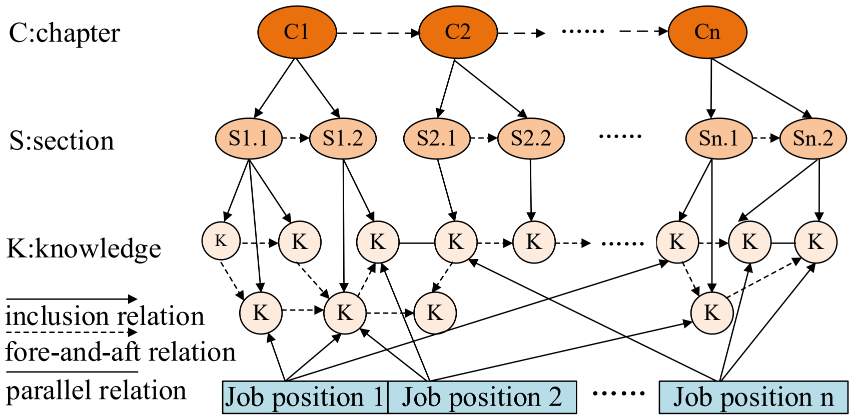

Fig. 7. Structure of curriculum knowledge and relations between knowledge points and jobs

5 Discussion and conclusion

Connecting relations among knowledge points can be reconstructed through the KG of artificial intelligence curriculums, thus forming a professional networked structural system of the subject to support flexible, accurate "teaching" and lifelong personalized "learning" effectively. To understand the state of the art of the KG of curriculums, improve the innovation and academic and application values of research contents, and avoid repeated studies, a statistical analysis of studies concerning the KG of curriculums was carried out, and an open KG design scheme was proposed. The following conclusions could be drawn:

1. Few constructions of KG for a specific curriculum have been established, and KG is still in its initial stage. This state can be explained through the following two aspects. Curriculum knowledge has very complicated types and structures; some curriculum knowledge is even difficult to structuralize, and the workload is very high. Moreover, the diversified changes of some subjects increase difficulties in forming gradient teaching teams, thus resulting in the failure of collaborative teaching. This study believes that this problem can be improved through the following aspects. First, the construction of teaching research teams must be strengthened; leaders, managers, theory teachers, and professional experimental technicians of various disciplines must also be encouraged to form a practice teaching team with reasonable age and knowledge structures, form academic gradient teams with continuous concern for practice teaching research, assure ordered progress in teaching reforms, and publish papers on research results continuously. Second, the attention of universities, especially top-class universities, on studies of practice teaching should be improved, and a good atmosphere for practice teaching should be created.
2. The KG of curriculums has two research directions. One is to explore the applications of artificial intelligence algorithms in KG construction. The other is to study the specific implementation of the KG construction of curriculums. Under these

two directions, researchers propose the application demonstrations of education-related KG in various scenes, such as intelligent teaching and intelligent learning.

3. The design of an open KG of artificial intelligence curriculums in university education is conducive to make knowledge point setting conform to enterprise needs. Through cooperation between teachers and engineers, boring classroom contents are connected with the requirements of a specific post, which is beneficial to improve the practice ability of students and avoid disconnection with practical applications. This cooperation is also conducive to the future career plans of learners.

The current research on leading edges and tendency related to the KG of curriculums is analyzed in this study. Results provide a reliable perspective and reference to education researchers and practitioners. However, this study is based on the existing literature on the CNKI database. Future studies can further analyze foreign studies and compared them with the relevant Chinese literature to provide references for further localized teaching practices. In this way, research results can serve the education field better. Moreover, the future development of intelligent education involves knowledge expression learning, knowledge acquisition, disciplinary knowledge reasoning, and computation. Deep studies on the basic theories and methods of large-scale education KG are some research directions in future.

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