Construction and Analysis of Knowledge Network: On the Example of Educational Technology Syllabus

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***Abstract*—The syllabus is the guiding document for subject teaching and the main basis for teacher teaching. The mastery of the teacher's knowledge structure of the syllabus marks the quality of teaching. Teachers should not only understand the basic content of the syllabus, but also be familiar with the overall structural characteristics of the syllabus. In this paper, we mainly applies the social network analysis method to research the structural characteristics of the syllabus. Firstly, according to the *Educational Technology* syllabus, its knowledge structure is analyzed. Then the concept map is used to construct its knowledge structured model, and the adjacency matrix is used to establish the knowledge network model. Secondly, through the analysis of the content of the *Educational Technology* syllabus, the relative knowledge nodes and knowledge relationships are ascertained, and the UCINET software is used to construct the *Educational Technology* knowledge network. Thirdly, the node centrality of the *Educational Technology* knowledge network is analyzed, three indicators of node centrality (degree centrality, betweenness centrality and closeness centrality) are used to respectively explain the importance, connectivity and difficulty of the knowledge node in the *Educational Technology* knowledge network. Finally, through the calculation and analysis of the central indicators, it can get that the centrality of the knowledge node is greater, this shows its position is more important, its connectivity is closer and its learning difficulty is smaller. And combining the analyzed results with the actual teaching, it can provide a new way to optimize the teaching.**

***Index Terms*—Social network, concept map, knowledge network construction, syllabus analysis.**

I. Introduction

With the development of information technology and the arrival of knowledge age, new technologies and new knowledge have grown rapidly, and human society has entered the era of "knowledge explosion" [1]. The society demands more and more intellectuals, which not only requires the mastery of knowledge, but also requires that knowledge be structured and networked. The syllabus is the guiding document of the course teaching [2], and it defines the teaching purpose and basic requirements of the subject, as well as the scope and structure of the subject knowledge. The syllabus shows the important and difficult points of teaching, and it makes the teachers understand the main contents of teaching. So the syllabus plays an important role in teaching activities [3]. The knowledge point is the basic unit of the syllabus, and the scientific syllabus has the characteristics of prominent knowledge content and compact knowledge structure [4]. Each knowledge point is interrelated through the certain logic, and it forms a knowledge system with a certain structure [5]. The knowledge network is a kind of high abstraction of knowledge system, and it focuses on the structural characteristics of knowledge. From the type of knowledge network, it is mainly divided into the following three types [6]: 1). The network between knowledge subjects, such as people, enterprises, etc. 2). The network between knowledge and people. 3). The network between knowledge and knowledge. In addition, looking at the existing knowledge network, they can be roughly classified into two categories [7]: One is the knowledge network that uses knowledge points as its node content. The other is the knowledge network that uses document or knowledge element of the knowledge document database as its node content. The knowledge network is a complex knowledge system, and it consists of many knowledge points and knowledge relationships. If only the words or statistics is used to represent the structure of the knowledge network, they may lead to the lack of information, and they are very difficult to observe [8]. The social network tool is used, and the knowledge network can be expressed intuitively. Then it is convenient to analyze the valuable information of the knowledge network.

Since 1998, the statistical results of the American Institute of Scientific Information (ISI) have shown: a large number of documents about social networks have been published in world class publications, such as *Nature*, *Science*, *PNAS*, *PRL*, etc. And this reflects from the side that social networks have become an emerging research hotspot [9]. The research of social networks has been gradually applied to many fields, such as physics, biology, engineering, economics, sociology and so on, and it has aroused the extensive attention of scientists [10]. Although social networks have been applied to so many fields, it has been found that few people combined it with the knowledge network in the field of teaching [8]. Because the knowledge network belongs to a kind of social network, we can use the social network analysis method to analyze the syllabus. The knowledge content of the syllabus can be abstracted by network model, then the knowledge structure of the syllabus can be described. And this also reflects that the knowledge content of the syllabus has the characteristics of logic and relevance. The social network analysis method focuses on analyzing social phenomena from the perspective of structure, treating the development of things from the perspective of relationship, and recognizing

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the relevance of the development of things [11]. The focus of knowledge networks is not only on the knowledge nodes themselves, but also on the relationships between knowledge nodes and their changing rules [12]. When people understand the formation mechanism of knowledge networks, some rules are summarized and represented by the knowledge network model [13]. At present, some teachers' understanding of the syllabus are mainly based on experience accumulation, and they lack systematic scientific analysis methods [4]. Therefore, it is particularly reasonable to apply the social network analysis method to quantitatively analyze the knowledge structure of the syllabus. The network model that describes the knowledge structure of the whole syllabus is constructed, and this network model can better reflect the logic and relevance between knowledge points. It can deepen the teacher's understanding of the knowledge structure of the whole syllabus, and it also plays a positive effect on the teaching process.

This paper mainly applies the social network analysis method to research the knowledge structure of the syllabus. The *Educational Technology* syllabus is the research object, and the knowledge point and knowledge relationship are research content. We can construct a knowledge network model that describes the knowledge structure of the whole syllabus. Then the node centrality of the knowledge network is analyzed, and the three indicators of node centrality (degree centrality, betweenness centrality, and closeness centrality) are used to comprehensively analyze the importance, the connectivity, and the difficulty of the knowledge node in the knowledge network. In this way, we can find out the knowledge node that plays an important role and influence, then the rationality and feasibility of knowledge network construction are verified. And combining the final analysis results with the actual teaching, it shows that teachers should grasp the important and difficult points of the syllabus, and realizing the innovation of teaching methods. In the end, it can improve the efficiency of teacher training.

II. Analysis of the *Educational Technology* Knowledge Structure

A. Knowledge Structure Model

Analyzing the knowledge structure according to the *Educational Technology* syllabus, the concept map is used to show the knowledge structure of the syllabus. Concept map is a tool used to represent knowledge, and it is a representation of thinking visualization. Concept map usually puts the concept of a subject in a square or circle, and the relevant concept and subject are connected with the line [14]. Concept map is not only a method to express traditional knowledge, but also has the characteristics of intuitive expression, easy to realize, close to natural language and so on. When concept map is represented by graph, it is a directed connected map. Concept map consists of two kinds of nodes [15]: the conceptual node and the conceptual relationship node. The conceptual node represents a concrete or abstract entity in the problem field. The conceptual relationship node represents the relationship between conceptual nodes. And the direction of the connection line represents the relationship between the conceptual node and the conceptual relationship node.

In the construction of the concept map of the *Educational Technology* syllabus, the formal definition of a concept map [15]: CM=(Concept, Relation, F). Among them, Concept=$\{c_1, c_2,...,c_n\}$, it is the set of conceptual nodes, that is, the knowledge points in the *Educational Technology* syllabus. Relation=$\{r_1,r_2,...,r_m\}$, it is the set of conceptual relationship nodes, that is, the relationship between knowledge points in the *Educational Technology* syllabus. $F \subseteq (\text{Concept} \times \text{Relation}) \cup (\text{Relation} \times \text{Concept})$, it is the set of connections, that is, the connection between the knowledge points and the corresponding knowledge relationships in the syllabus. In the representation of the concept map, the conceptual nodes are represented by square frames, the conceptual relationship nodes are represented by circles. And the lines mark the conceptual nodes connected by the conceptual relationship nodes. Representation of the concept map is shown in Fig. 1:

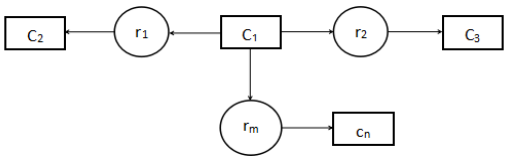

Fig. 1. Representation of the concept map.

The *Educational Technology* syllabus includes a number of knowledge points and many relationships among them. The following is explained from two aspects: knowledge points and knowledge relationships. Knowledge points in the syllabus mainly appear in the teaching content of each chapter, and many knowledge points have been formed due to various knowledge relationships. Then many knowledge points in the syllabus can be divided into key knowledge and difficult knowledge. Besides, there are many kinds of knowledge relationships in the syllabus, for example [16]: precursor relationship, successor relationship, inclusion relationship, dependency relationship, same relationship, etc. Some knowledge relationships are illustrated in the *Educational Technology* syllabus in Table I:

TABLE I: Examples of Knowledge Relationships Analysis Table

Knowledge relationships	Examples
Precursor relationship	The definition of educational technology is the precursor of the development of educational technology.
Successor relationship	The development of educational technology is the successor of the definition of educational technology.
Inclusion relationship	The theoretical basis of educational technology includes constructivism learning theory.
dependency relationship	The knowledge content of subsequent learning depends on the generation of the basic concepts of educational technology.
Same relationship	The definitions of educational technology 94 and 05 all explain the basic concepts of educational technology.
…	…

The number of knowledge points constitutes the scale of

the knowledge structure of the syllabus, and the relationship between the knowledge points indicates the characteristics of knowledge structure of the syllabus. In the *Educational Technology* syllabus, because of these numerous knowledge points and diverse knowledge relationships, the complex knowledge structures are formed. Through above analyzing of knowledge points and knowledge relationships in the *Educational Technology* syllabus, the knowledge structured model of the syllabus is shown in Fig. 2:

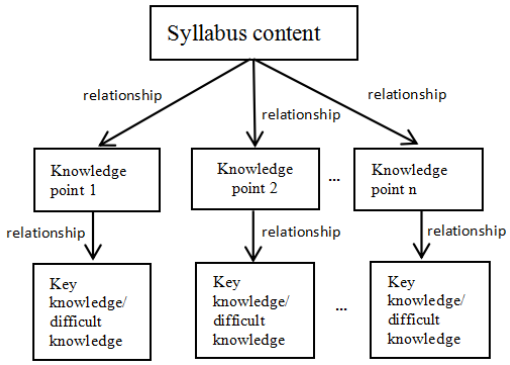

Fig. 2. Knowledge structured model of the *Educational Technology* syllabus.

B. Knowledge Network Model

The knowledge structure can be simply expressed by the knowledge structured model, then all knowledge points and knowledge relationships can not be shown completely. Now we consider using the knowledge network model to show the various knowledge points and complex knowledge relationships. In the *Educational Technology* syllabus, there are many knowledge points and knowledge relationships. In order to facilitate research and analysis, it is easier to establish a knowledge network topology graph. The knowledge structure of the *Educational Technology* syllabus can be expressed through a network model, and it forms a knowledge network. The knowledge network is a kind of network knowledge system which is composed of knowledge nodes and knowledge relationships [17]. If we want to fully describe the knowledge nodes and knowledge relationships in the syllabus, all knowledge nodes and knowledge relationships can be represented by an adjacency matrix. In this way, a knowledge network model which can reflect the knowledge structure of the whole syllabus is formed.

This knowledge network model is a mathematical abstraction of the actual knowledge network, and it is a model that describes the relationship between the knowledge network and internal elements. Meanwhile, it contains many knowledge nodes and knowledge relationships. The knowledge node of the network contains not only its own information, but also the influence of a knowledge node on other knowledge nodes. That is, the knowledge network is a graph with the certain attributes and functions [8]. The *Educational Technology* knowledge network can be expressed as a graph consisting of point sets and edge sets, and it can be recorded as $G=(V,E)$. Where, V represents the set of all knowledge points in the *Educational Technology* knowledge network. $V=\{v_1,v_2,...,v_n\}$, it represents n knowledge points in the graph. E represents the set of associations between all knowledge points in the *Educational Technology* knowledge network. $E=\{e_1,e_2,...,e_m\}$, it represents that there are m connected edges between the knowledge nodes in the graph. $(v_1,v_n)\in E$, it indicates that the knowledge point v_1 is associated with the knowledge point v_n, then there are connected edges between the knowledge point v_1 and the knowledge point v_n in the graph.

In the *Educational Technology* knowledge network, knowledge nodes and their connections are expressed by means of adjacency matrices. In the knowledge network $G=(V,E)$, if nodes v_1 and v_n are connected, then it is said that there is a correlation between v_1 and v_n. The adjacency matrix of the knowledge network $G=(V,E)$ can be expressed as a square matrix $A=[A_{ij}]$. That is, it represents as a matrix of $n\times n$, this $n\times n$ matrix can be specifically expressed as equation (1):

$$A=\begin{bmatrix} a_{1,1} & a_{1,2} & \dots & a_{1,n} \\ a_{2,1} & a_{2,2} & \dots & a_{2,n} \\ \dots & \dots & \dots & \dots \\ a_{n,1} & a_{n,2} & \dots & a_{n,n} \end{bmatrix} \tag{1}$$

In addition, when judging whether there is a relationship between knowledge nodes or not, it depends on whether they have a knowledge association or not, and it is expressed by values 0 and 1. When there is a relationship between knowledge points in the *Educational Technology* syllabus, they are considered to be associated, and marked it as 1. Otherwise, they are considered to be unassociated, and marked it as 0. Then the elements in the matrix can be specifically expressed as in equation (2):

$$A_{i,j}=\begin{cases} 1, & \text{If node i is related to node j} \\ 0, & \text{If node i has no relationsh ip with node j} \end{cases} \tag{2}$$

In this way, the adjacency matrix can be established according to the *Educational Technology* syllabus. From this adjacency matrix, each knowledge node can be seen intuitively, and whether there is a relationship between knowledge nodes or not. In the *Educational Technology* knowledge network, when there is a relationship between knowledge points, the two knowledge nodes are connected by a line. Conversely, when there is no relationship between knowledge points, there is no line connection between the two knowledge nodes.

III. Construction of the *Educational Technology* Knowledge Network

A. Collection of Data

In this paper, the syllabus of *Educational Technology* is collected from universities such as Yunnan Normal University, Jiangxi Normal University, and Shandong Normal University, etc. By analyzing the text of the *Educational Technology* syllabus, using structured and graphical methods, and considering each knowledge point and their relationship, the adjacency matrix of the

Educational Technology syllabus can be established. By analyzing all the knowledge points and their relationships in the *Educational Technology* syllabus, the *Excel* spreadsheet is used to record data information, and completing the process of data collection. The data collection process is strictly based on the *Educational Technology* syllabus, and the data is comprehensive and true.

B. Determination of Nodes and Relationships

When the knowledge network is constructed, the knowledge nodes of the knowledge network firstly should be determined, then the knowledge relationships between the knowledge nodes should be established. From the perspective of the knowledge points and their relationships, two basic principles should be followed [4]: objectivity and comprehensiveness. Objectivity means that knowledge points and their relationships are completely dependent on the *Educational Technology* syllabus itself. Comprehensiveness means that knowledge points and their relationships cover all kinds of knowledge points and their possible relationships.

From the *Educational Technology* syllabus, 76 knowledge nodes were extracted, and 1917 knowledge relationships were corresponding identified. Finally, the adjacency matrix of the *Educational Technology* knowledge network can be expressed as a matrix, that is, it represents a matrix of 76×76. These knowledge points and their relationships indicate the overall structural characteristics of the *Educational Technology* syllabus, and it also provides the research data for the construction of knowledge network. Number of knowledge nodes and knowledge relationships is shown in Table II:

TABLE II: NUMBER OF KNOWLEDGE NODES AND KNOWLEDGE NODES AND KNOWLEDGE RELATIONSHIPS

Knowledge content	Number
Knowledge nodes	76
Knowledge relationships	1917

C. Establishment of Educational Technology Knowledge Network Topology Graph

According to the predefined the knowledge structured model and knowledge network model. And on the basis of the established adjacency matrix of the *Educational Technology* syllabus, using UCINET software to analysize the *Educational Technology* knowledge network and realize visual operation. In this way, we can get the *Educational Technology* knowledge network topology graph, and it is shown in Fig. 3:

From the above *Educational Technology* knowledge network topology graph, we can see: It can describe the characteristics of the whole knowledge structure of the *Educational Technology* syllabus. And comparing with traditional methods, it is more objective, more comprehensive and more detailed to describe the knowledge structure and the whole characaters of the *Educational Technology* syllabus. Nextly, it is more convenient to analyze the attributes and characteristics of the *Educational Technology* knowledge network, and the rationality and feasibility of knowledge network construction will be further verified.

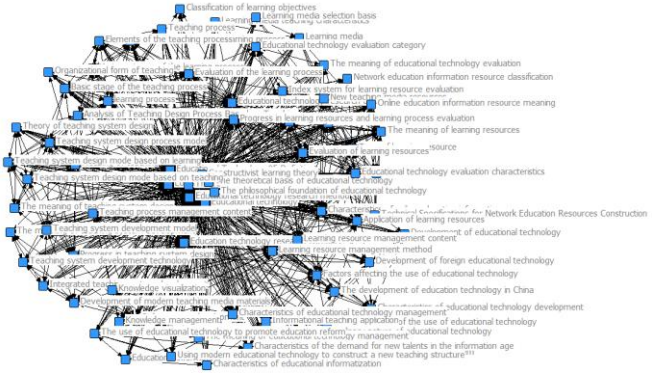

Fig. 3. *Educational Technology* knowledge network topology graph.

D. Analysis of Node Centrality of the Educational Technology Knowledge Network

Currently, it has been proposed in the social network: the node centrality is used to measure the importance of nodes, and there are three representative central indicators[18]: degree centrality, betweenness centrality, and closeness centrality. 1). Degree centrality measures the importance of nodes by calculating the number of edges connected to a node, and it reflects the connectivity between nodes. 2). Betweenness centrality measures the importance of nodes by calculating the number of shortest paths to a node, and it reflects the influence of the node. 3). Closeness centrality measures the importance of nodes by calculating the difficulty of a node reaches other nodes, that is, the distance between nodes.

TABLE III: CENTRAL INDICATORS OF THE EDUCATIONAL TECHNOLOGY KNOWLEDGE NETWORK NODE (TOP 10)

Serial number	Knowledge point	Degree centrality	Betweenness centrality	Closeness centrality
1	Educational technology	75.000	430.256	100.000
2	Philosophical basis of educational technology	75.000	430.120	98.684
3	Theoretical basis of educational technology	75.000	430.256	100.000
4	Constructivism learning theory	75.000	430.256	100.000
5	Research methods of educational technology	74.000	403.388	98.684
6	Research Orientation of Educational Technology	74.000	406.339	97.403
7	Educational technology 05 definition	71.000	357.113	94.937
8	Educational technology 94 definition	71.000	357.113	94.937
9	Education technology research category	48.000	142.514	73.529
10	Educational technology research object	45.000	97.854	70.755

The node centrality of *Educational Technology* knowledge network is analyzed by using UCINET software, and

choosing degree centrality, betweenness centrality, and closeness centrality as three indexes to measure the importance of knowledge network nodes [19]. The problems that can be explained from the centrality aspect of the knowledge network node: 1). Whose are the key learning knowledge point when learning the knowledge points; 2). How is the relationship between knowledge poins; 3). How difficult is the key basic knowledge point to influence other knowledge points. Through the calculation of the established adjacency matrix, the central indicators of the *Educational Technology* knowledge network node are obtained. The specific values are shown in Table III: Only the top 10 items are listed here, it shows the knowledge point is the higher ranking in the knowledge network, then whose importance is bigger, whose connection is closer, and whose learning difficulty is smaller. These key basic knowledge points are the foundation of the subsequent knowledge point to learn.

1) Degree centrality

The degree centrality reflects the importance of knowledge nodes in the knowledge network, and it also embodis the specific location of a knowledge point in the entire knowledge network. In the *Educational Technology* knowledge network, according to the definition of degree centrality and by calculation, it can get: the maximum degree centrality of the knowledge node is 75, the minimum degree centrality of the knowledge node is 10, and the maximum value is 7.5 times as large as the minimum value. According to this analysis value, the difference between key knowledge and non-key knowledge can be displayed. When learning these knowledge points, we should pay attention to distinguish the importance and basis of each knowledge point. In the learning process of knowledge points, these basic theories, methods and concepts should be as the key basic knowledge to learn. Only by mastering these key basic knowledge, we can better learn the follow-up new knowledge. That is, these key basic knowledge is the starting point of learning other knowledge points.

2) Betweenness centrality

The betweenness centrality reflects the connection ability of a knowledge node and other knowledge nodes, and it is a description of "intermediary" ability and "bridge" function between knowledge nodes. According to the definition of betweenness centrality and by calculation, it can get: the maximum betweenness centrality of the *Educational Technology* knowledge network is 430.256, the minimum value is 0.028, the central potential is 6.95%, and the standard deviation of the betweenness centrality is 68.216. These data can indicate: betweenness centrality of the *Educational Technology* knowledge network of has the certain difference, and the maximum value is 6.307 times that of the average value. It shows that the connection ability of each knowledge point in the knowledge network is different, some knowledge points are closely connected with other knowledge points, and mastering these knowledge points is beneficial to the learning of other knowledge points. In the *Educational Technology* knowledge network, the knowledge node which has the greater the betweenness centrality is at the more middle position. These knowledge points play a larger role to learn other knowledge points, and it also has a certain impact on other knowledge points learning. Thus, in the process of learning these knowledge points, they need to be learned as the key knowledge. We can see from TABLE III: Educational technology, Philosophical basis of educational technology, Theoretical basis of educational technology and Constructivism learning theory are in the top four. These basic concepts and theories can be taken as key knowledge points to learn, and these key knowledge points are the "bridges" and "ties" to connect with other knowledge points. If we neglect these key knowledge points, the shortest path of the knowledge network node becomes larger, reducing the connectivity of the knowledge network, and affecting the effect of learning the follow-up knowledge points. So learning these key knowledge points cannot be ignored.

3) Closeness centrality

The closeness centrality reflects the difficulty and close degree of one knowledge node affecting to reach other knowledge nodes. According to the definition of closeness centrality and by calculation, it can get: the maximum closeness centrality of the *Educational Technology* knowledge network is 100, the minimum value is 53.571, and the maximum value is 1.866 times that of the minimum value. These values show that most of the knowledge nodes have the greater closeness centrality, reducing the distance between knowledge nodes in knowledge networks, and the logic and relevance between knowledge points is enhanced stronger. For example, Educational technology, Basic theory of educational technology, Research methods of educational technology, etc. These basic concepts, theories and methods are the basic knowledge to learn, and they are closely related to other knowledge points. Then the logics and relevance between knowledge points are increased, and the difficulty to learn these knowledge points is also reduced. When we learn these basic knowledge points, the learning difficulty is not big, and they are easy to be learned. The learning of these basic knowledge points should not be regarded as the difficult knowledge, not spend too much time on them. Otherwise, it would be a waste of time. Too much time to learn these basic knowledge points, it makes the learning of all knowledge points lose balance, and it also makes the following knowledge points not get enough learning time. In learning these basic knowledge points, they can be used as a starting point, but it is also necessary to allocate the learning time of the subsequent knowledge points. Simultaneously, arranging the reasonable teaching time, and the teaching efficiency of teachers can improved.

From analyzing of the node centrality of the *Educational Technology* knowledge network, the three indicators of node centrality describe the different importance levels of knowledge nodes in the *Educational Technology* knowledge network, and reducing the one-sided influence of the single index on the analysis results [20]. From the above analysis of three centrality indicators of the knowledge node, it can be concluded [21]: The knowledge node has the bigger centrality, then it shows whose position in the knowledge network is more important, whose connectivity is closer, and whose learning difficulty is smaller, such as Educational technology, Philosophical basis of educational technology,

Theoretical basis of educational technology, etc. These key basic knowledge points are closely related to other knowledge points, and they also have the certain bridge connection function in other knowledge points. These key basic knowledge points occupy a very important position in the *Educational Technology* syllabus, and they played a great influence and role. So it is reasonable and feasible to put these basic concepts, theories and methods in the beginning of the syllabus to learn.

Here, some suggestions can be obtained: Teachers should apply the analysis results of the *Educational Technology* knowledge network to classroom teaching. Through the node centrality indicators (degree centrality, betweenness centrality, and closeness centrality) of the *Educational Technology* knowledge network, the importance and difficulty of *Educational Technology* knowledge points can be judged scientifically. Therefore, in the actual teaching process, teachers should pay attention to the study of the key knowledge and difficult knowledge according to the node centrality of the knowledge network. Then grasping the important and difficult knowledge points, improving teaching methods, the goal of optimizing education and teaching is achieved.

IV. Conclusion

This paper is mainly based on the social network analysis method, constructed the *Educational Technology* knowledge network. Then combined with the practical teaching problems, the node centrality of the *Educational Technology* knowledge network is analyzed, and the individual attributes of the *Educational Technology* knowledge network is obtained. Finally, the rationality and feasibility of the knowledge network construction are verified. However, the entire attribute of the *Educational Technology* knowledge structure needs to be further studied, and there is still a lot of research spaces for the constructed knowledge network. In the future research, we should combine the teaching practice, improving knowledge relationships between knowledge points, and achieving the goal of optimizing the knowledge structure. Then the syllabus as the guiding document of the course teaching will also be discussed in future, this can better realize the teaching process and requirements. At the same time, the research of knowledge network can be extended to the other teaching field.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Jing Xia Liu, Bin Wen conducted the research; Jing Xia Liu, Bin Wen analyzed the data; Jing Xia Liu, Bin Wen wrote the paper; all authors had approved the final version.

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