Advances in Educational Technology and Psychology (2026)
Clausius Scientific Press, Canada
DOI: 10.23977/aetp.2026.100202
ISSN 2371-9400 Vol. 10 Num. 2

Construction and Implementation Path of CiteSpace-Enabled Research-Based Teaching Model from the Perspective of Cognitive Tools

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Keywords: Research-Based Teaching, Cognitive Tools, CiteSpace, Teaching Model

Abstract: In 2005, the Ministry of Education put forward "research-based teaching" in Several Opinions on Further Strengthening Undergraduate Teaching in Institutions of Higher Education, emphasizing guiding students to conduct inquiries around frontier issues through diversified teaching methods. Against this background, research-based teaching has gradually become an important direction of higher education teaching reform. However, in the practical implementation of teaching, it is found that some students have difficulties in grasping the overall research fields involved in classroom topics and putting forward research questions. To address this deficiency, based on constructivist teaching theory, this paper introduces the literature visualization analysis tool CiteSpace to construct a research-based teaching model of "structure comprehension–question raising". Taking literature data as the basic resource, this model presents the overall structure of research fields through knowledge mapping, guides students to identify research contexts and potential gaps on the basis of overall cognition, and further promotes the raising of research questions, realizing the transformation from knowledge cognition to research ability cultivation. This paper systematically elaborates the model from three aspects: theoretical basis, model structure and implementation path.

1. Introduction

With the continuous deepening of higher education reform, increasing emphasis has been placed on cultivating students' scientific research literacy, problem awareness and critical thinking in teaching. In this context, as a teaching paradigm that integrates the learning process and the research process, research-based teaching has gradually become an important orientation of higher education teaching reform. Nevertheless, research-based teaching still faces many dilemmas in practice. On the one hand, although flipped classrooms and other forms have been adopted in classrooms, research questions are mostly preset by teachers, and students lack the awareness and ability to actively generate research questions. On the other hand, in the process of literature reading, students often only stay at the superficial sorting of subject keywords, failing to grasp the overall

structure of the research fields involved in the topics, and thus struggling to extract questions with research value. As a result, research-based teaching has become a mere formality to a certain extent, failing to truly realize the transformation from "knowledge learning" to "research practice". How to use technical means to help students clearly understand the overall structure of a research field and put forward research questions on this basis has become a key problem urgently to be solved in current research-based teaching. In view of this, this paper introduces the literature visualization analysis tool CiteSpace, explores its transformation path in teaching situations under the framework of constructivism and cognitive tool theory, and constructs a research-based teaching model centered on "structure comprehension – question raising". It should be noted that this paper focuses on the construction and theoretical demonstration of the teaching model, without involving empirical evaluation of specific teaching effects, and its effectiveness needs to be further tested in follow-up studies[1-3].

2. Research-Based Teaching from the Perspectives of Constructivism and Cognitive Tools

2.1. Research-Based Teaching in China

The "dialogue" between the Chinese educator Confucius and his students, as well as the "Socratic method" of the Western philosopher Plato, have provided enlightenment for "research-based teaching", constructing high interaction between teachers and students in the teaching process and reflecting the exploration of problems by teachers and students. The "research" function of universities originated from the University of Berlin founded in 1810, providing a foundation for "research-based teaching". From the late 19th century to the mid-20th century, American educators such as Dewey and Bruner conducted in-depth explorations on "scientific inquiry", "discovery teaching" and "inquiry-based learning" respectively, providing necessary theoretical support for the practice of "research-based teaching". In the mid-to-late 1960s, the educational reformer V. A. Sukhomlinsky founded a new teaching method—research-based learning method after long-term exploration and extensive experiments. After the 1980s, teaching methods became increasingly diverse, and foreign scholars generally believed that research-based teaching focuses more on developing abilities, but teachers and students must work together to design a shared research and learning space.

In 2005, the Ministry of Education of the People's Republic of China issued Several Opinions on Further Strengthening Undergraduate Teaching in Institutions of Higher Education (Jiao Gao [2005] No. 1), and the term "research-based teaching" appeared in higher education documents for the first time. It was recommended that teaching adopt flexible application of various teaching methods to guide college students to discuss frontier issues, so as to improve their autonomous learning and innovative abilities. Some scholars proposed that the curriculum and teaching system of "research-based learning" in higher education can realize the integration of learners' and researchers' dual roles. Some scholars summarized the characteristics of research-based teaching as transcendence of teaching objectives, generativity of teaching content, exploration of teaching process, extensiveness of teaching time and space, development of teaching evaluation, and mutual progress of teacher-student relationship. Other scholars argued that the characteristics of research-based teaching are reflected in problem-oriented, processual, open, dynamic, independent, forward-looking and participatory nature. In short, scholars have explored the characteristics of research-based teaching from different perspectives. Through sorting out, the characteristics of research-based teaching can be summarized as: inquiry-based, processual, dynamic and participatory.

2.2. Constructivist Learning View, Cognitive Tool CiteSpace and Research-Based Teaching

Chinese scholars generalize the teaching model adapted to constructivist learning theory as: student-centered, with teachers acting as organizers, guides and facilitators in the teaching process, and guiding students to actively participate in learning through learning environment elements such as situation, collaboration and conversation, so as to realize the meaningful construction of knowledge. From this perspective, the learning process is essentially a process in which learners integrate and reorganize new information on the basis of their original cognition, and gradually form an understanding of the knowledge structure. Accordingly, for teachers, the core of teaching is no longer the presentation of knowledge content, but the design of learning situations and the guidance of cognitive activities. Research-based teaching emphasizes problem-oriented guidance for students to participate in the inquiry process, which is inherently consistent with the "active construction" emphasized by constructivism.

However, in actual teaching, when facing a large number of scattered literatures, students often fail to grasp the overall existing achievements of research topics, and the literature retrieval process is also scattered and unsystematic, thus affecting their ability to discover and put forward research questions. This phenomenon indicates that there is a lack of an effective way to present and guide the research structure in the current teaching and learning process, making it difficult for students to form a clear understanding of the knowledge structure of existing achievements. In this context, introducing cognitive tools that can support the understanding of knowledge structure has become a necessary path. Some scholars pointed out that cognitive tools can help learners organize and represent their original knowledge, absorb new information into their internal knowledge structure, or reorganize their cognitive structure, and use this new structure to explain and infer new knowledge. Thus, the learning process shifts from simple information reception to cognitive activities centered on knowledge structure comprehension.

Based on the above theoretical framework, CiteSpace can be regarded as a typical cognitive tool. It can centrally display the evolution process of a knowledge field on a citation network map, and automatically mark the cited node documents as the knowledge base and the research frontiers characterized by co-citation clusters on the map. Introducing CiteSpace into the teaching process helps students grasp the overall structure of research fields, identify connections and changes among them, discover potential research spaces on this basis, and then put forward research questions. From a teaching perspective, this process essentially transforms the literature analysis tool into a cognitive medium supporting "structure comprehension–question raising", thus providing methodological support for the construction of the research-based teaching model[4-5].

3. Framework of the "Structure Comprehension – Question Raising" Research-Based Teaching Model Based on CiteSpace

To present the "structure comprehension–question raising" research-based teaching model based on CiteSpace more intuitively, this paper constructs a teaching model as shown in Table 1. Centered on students' learning process, the model is divided into three progressive stages according to the logic of cognitive development: input layer, cognitive layer and output layer, reflecting the gradual deepening process from information acquisition to knowledge structure comprehension and then to question raising.

Table 1: The Teaching Model

Level	Teaching Objectives	Teaching Process	Core Tasks	Cognitive Process	Data Sources /Cognitive Tools
Input Layer	Form a preliminary understanding of research topics	Literature acquisition stage: Teachers guide students to determine themes, retrieve literatures, and complete data screening and sorting	Build research foundation	From scattered information to preliminary cognition	Literature databases
Cognitive Layer	Grasp the overall knowledge structure of research fields	Knowledge structure comprehension stage: Teachers guide students to conduct map analysis and interpretation to understand the overall structure of research fields	Form overall cognition	From content comprehension to knowledge structure comprehension	CiteSpace
Output Layer	Develop the ability to raise research questions	Question raising stage: Teachers guide students to identify research gaps, refine questions and form research topics	Form research questions	From knowledge structure comprehension to question raising	CiteSpace

At the input layer, teaching starts with literature acquisition, organizing students to conduct literature retrieval and data sorting around research topics. At this stage, teachers mainly guide retrieval strategies and data screening, lead students to clarify research themes, set keywords, obtain relevant materials through literature databases, and complete the collection and sorting of basic data. In this process, students shift from passive reception to active information searching, gradually getting in touch with relevant content of research fields and realizing the transition from scattered information to preliminary cognition. The core of this stage is to provide the necessary data foundation for subsequent learning and enable students to form a preliminary understanding of research topics.

At the cognitive layer, teaching focuses on knowledge structure comprehension. With the help of CiteSpace, visual analysis is carried out on the literature data obtained in the early stage to generate knowledge maps, and interpretation activities are carried out around the maps. In this process, teachers guide students to understand keyword co-occurrence, cluster structure, time evolution and other analysis results, helping them identify the relationships and development contexts between research themes. Through the visual presentation of maps, originally scattered literature information is integrated into a structural system with internal connections, enabling students to grasp the overall knowledge composition and changing characteristics of research fields, thus realizing the transformation from knowledge content comprehension to knowledge structure comprehension. This stage is a key link of the teaching model, and its core is to promote students to form overall cognition[6-7].

At the output layer, teaching further points to the raising of research questions. On the basis of the knowledge structure comprehension formed in the previous stage, teachers guide students to identify potential gaps and development directions in research fields, and gradually refine research questions by comparing the connections and differences between different research themes. In this process, students are no longer limited to understanding existing research, but begin to re-analyze

research fields based on existing cognition, thus forming targeted research questions. This stage realizes the transformation of learning from understanding existing knowledge to developing research ability, and its core goal is to improve students' ability to raise research questions.

Based on literature data and mediated by knowledge maps, this teaching model constructs a complete learning path from information acquisition to knowledge structure comprehension and then to question raising through the progressive connection of the input layer, cognitive layer and output layer. Among them, literature databases mainly undertake the function of data sources, while CiteSpace, as the core cognitive tool, supports students to form overall cognition through the visual presentation and analysis of research structure, and further promotes the raising of research questions.

It should be noted that this paper mainly constructs and elaborates the "structure comprehension–question raising" research-based teaching model from the theoretical and methodological levels, without empirically testing its specific teaching effects. In practical application, the model can be appropriately adjusted according to the characteristics of different disciplines and course contents, and its core is to support students to form overall cognition through cognitive tools and raise questions on this basis. Follow-up studies can further explore the implementation effect and application scope of the model combined with specific teaching situations.

4. Teaching Implementation Path

In the specific implementation of the "structure comprehension–question raising" research-based teaching model, the teaching process can be refined into four interconnected links: tool introduction, literature analysis, structure interpretation and question raising. Each link is progressive in function, jointly forming a complete path from data acquisition to structure comprehension and then to question raising.

In the tool introduction link, the teaching focus is not only to help students master the basic operation methods of CiteSpace, but also to guide them to understand the functional positioning of the tool in revealing research structure. Teachers can select representative research topics through demonstration, complete the whole process from literature import to map generation on site, and explain the meanings of analysis results such as keyword co-occurrence relationships, cluster structure and time evolution combined with specific maps. In the explanation process, teachers should focus on guiding students to pay attention to the research information reflected by node size, connection strength and cluster distribution in the maps, so that they can realize that maps are not simple data visualization results, but a concentrated presentation of the structural relationships of research fields. At the same time, by comparing different map examples, students can be helped to understand the impact of different analysis parameters on results, thus initially establishing the corresponding relationship between "map presentation–structural relationship–research field". Through this link, students can shift from simple tool operation to understanding the cognitive function of tools, laying a foundation for subsequent structure comprehension.

In the literature analysis link, the organization and standardization of learning tasks should be further strengthened. Teachers can set a clear operation framework around specific research topics, such as limiting the time range of literature retrieval, keyword combination methods and literature source types, and explaining data screening criteria. On this basis, students conduct literature retrieval and sorting in groups, completing steps such as data collection, format conversion and import processing. To avoid randomness in students' operation, teachers can require them to record retrieval paths and screening basis, and conduct basic statistics and explanation of the obtained data. Subsequently, students use CiteSpace to generate preliminary knowledge maps, and observe and record the main nodes, cluster number and overall distribution in the maps. Through this process,

students not only complete the acquisition of research materials, but also gradually develop the awareness of systematic sorting and standardized processing of literature data, thus providing a reliable data foundation for subsequent structure interpretation.

In the structure interpretation link, the teaching focus shifts to in-depth analysis and overall understanding of knowledge maps. Teachers can adopt a problem-driven approach to guide students to conduct multi-level analysis around the maps. For example, identify the distribution pattern of research themes from the overall level, analyze the relationship structure between different clusters from the local level, and observe the phased changes of research development combined with the time dimension. In group discussions and classroom presentations, students need to express and explain the map interpretation results, and teachers correct and deepen their understanding through questioning and commenting. To further improve the analysis quality, teachers can also guide students to combine map results with specific literature content, so as to avoid superficial interpretation of maps. Through this link, scattered information is integrated into a structural system with internal connections, and students gradually form an overall cognition of research fields, realizing the transformation from content comprehension to structure comprehension.

In the question raising link, the teaching goal is to guide students to transform the formed structure comprehension into research questions. Based on the results of map analysis, teachers can guide students to think from multiple dimensions, such as identifying research gaps, analyzing the connection relationships between themes, and paying attention to the changing trends of research development. In specific operation, examples can be shown to demonstrate how to transform the above analysis into question expressions, such as transforming "few literatures in a certain research direction" into "whether there are under-explored issues in this field". On this basis, students try to put forward preliminary research questions, and compare and revise them through group discussions to gradually improve the pertinence and clarity of question expressions. In this process, teachers should focus on the researchability and academic value of the questions, and conduct guiding evaluations on the questions raised by students. Through this link, students gradually develop the ability to raise research questions on the basis of overall cognition, realizing the transition from knowledge comprehension to research ability cultivation.

Among the above four links, CiteSpace, as the core cognitive tool, not only supports the processing and visual presentation of literature data, but also acts as an intermediary connecting information and comprehension in the learning process.

5. Model Characteristics and Theoretical Significance

Overall, the CiteSpace-based "structure comprehension–question raising" research-based teaching model is not a simple integration of existing teaching processes, but forms structural characteristics with internal consistency in terms of cognitive path, question formation method and tool application.

Firstly, the model reflects a reconstruction of cognitive path centered on structure comprehension. Different from the linear presentation of traditional teaching centered on knowledge content, this model takes literature data as the basic resource, visually presents the distribution, relational structure and evolution process of research themes through knowledge maps, and guides students to grasp the overall composition of research fields. In this process, learning activities shift from understanding scattered information to overall grasping of knowledge structure, realizing the transformation from content comprehension to structure comprehension. Thus, the cognitive starting point of research-based learning is redefined as "structure comprehension", providing a necessary cognitive premise for subsequent question raising.

Secondly, the model reflects a generation mechanism based on structural analysis in the question

raising link. Although traditional research-based teaching emphasizes problem orientation, in practice, question raising often relies on students' personal experience and lacks clear analytical basis. This model presents research gaps, thematic relationships and development trends through knowledge maps, enabling students to think about questions on the basis of analyzing research structure. Under this framework, research questions no longer come from intuitive judgment, but are based on the identification of structural characteristics, making the question raising process more targeted and logically grounded. This question formation method supported by structure comprehension constitutes an important feature that distinguishes this model from general inquiry-based teaching.

Thirdly, the model reflects the application orientation of deep embedding of cognitive tools in the teaching process. In traditional teaching, technical tools are mostly used for information acquisition or result display, and the cognitive function of learners in the learning process is not fully exerted. This study introduces CiteSpace as the core cognitive tool into teaching, making it participate in the formation of learners' cognitive structure through the generation and interpretation of knowledge maps. Tools are no longer external aids, but important intermediaries connecting literature data and structure comprehension. In this process, teachers' role shifts from knowledge imparting to cognitive guidance, and the teaching focus shifts from content explanation to structure analysis, thus promoting the transformation of teaching methods from "teacher-centered" to "student-centered".

Through the collaborative reconstruction of cognitive path, question formation mechanism and tool application mode, this model integrates the two key links of "structure comprehension" and "question raising" to form a teaching system with internal logical consistency. In this sense, this model not only provides an operable implementation path for research-based teaching, but also offers a new analytical perspective for the application of cognitive tools in higher education.

6. Conclusions

Against the background of university teaching reform, based on constructivist teaching theory, this paper constructs a "structure comprehension–question raising" research-based teaching model with CiteSpace as the core cognitive tool, focusing on the practical problems that students are difficult to form overall cognition and lack the ability to discover problems in the learning process. Taking literature data as the basic resource, this model realizes the visual presentation of research field structure through knowledge maps, and organically connects structure comprehension and question raising through the progressive design of input layer, cognitive layer and output layer, thus providing a clear implementation path for research-based teaching.

Theoretically, this paper integrates constructivist teaching theory and cognitive tools, emphasizing the raising of research questions on the basis of structure comprehension, further enriching the implementation path of research-based teaching. Methodologically, by introducing CiteSpace as a cognitive tool, the originally scattered literature analysis process is transformed into a visual structure comprehension process, shifting learning activities from content comprehension to structure comprehension, and promoting the formation of research questions on this basis, thus improving the organization and directivity of the teaching process.

It should be noted that this paper mainly analyzes from the perspective of model construction and implementation path, without empirically testing the application effect of this teaching model in specific teaching situations. Follow-up studies can carry out teaching practice combined with courses of different disciplines to further explore the applicability of the model and its impact on the development of students' research ability, so as to continuously improve the implementation mechanism of research-based teaching.

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