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A Comparative Study of Old and New Teaching Materials Based on ISM—A Case Study of "Plane Vector and Its Application"

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Abstract: *Plane vector has an important role in the high school mathematics. The structure system of the chapter "Plane vector and its application" in the new textbook of human education edition has changed greatly. Based on ISM, this paper analyzes the specific changes of the "plane vector and its application" of the old and new textbooks, and compares them from four aspects: the selection of knowledge elements, the arrangement of the initial elements, the arrangement of the highest elements, the formation relationship between knowledge elements and the compilation system of textbooks. The results show that the new teaching material lays mo re emphasis on the integrity of knowledge elements; The new textbooks attach importance to the infiltration study of the essence of vector; The new textbook fully highlights the instrumental role of vector; The arrangement system of new textbooks lays more emphasis on the systematic learning of knowledge.*

Keywords: *ISM; Old and new teaching materials; Plane vectors and their applications*

1. Introduction

After the issue of "Mathematics Curriculum Standard for Ordinary Senior High Schools (2017 Edition)" (hereinafter referred to as "New Curriculum Standard"), the textbook was rewritten according to the training objectives, curriculum nature and new concepts of curriculum standard. Mathematics textbooks provide learning themes, basic clues and specific contents for "teaching" and "learning" activities, and are important teaching resources to realize the teaching curriculum objectives and develop students' core literacy in mathematics.[1]In 2019, People's Education Society published "Compulsory Mathematics Volume II (Version A) of Ordinary High School Textbook" (hereinafter referred to as "new textbook"), which was written on the basis of "New Curriculum Standard". Compared with "Mathematics Compulsory Course 4 (Version A)" (hereinafter referred to as "the old textbook") published by People's Education Society in 2004, the new textbook breaks the arrangement of modular structure of the original textbook and is divided into themes, which ensures the systematicness and structural integrity of mathematics knowledge and makes the logical order of the content more reasonable[2].

In order to make better use of the new textbooks, and give full play to the role of the new textbooks in cultivating students' core literacy in mathematics, it is necessary to clarify the changes in the arrangement system of the old and new textbooks and clarify the internal and logical relations between the knowledge of the new and old textbooks. At present, there are various methods used by educational researchers to compare teaching materials. ISM method has unique advantages in sorting out the arrangement system of teaching materials, which can reveal the complex relationship between knowledge elements and finally form a clear hierarchical directed graph.

Plane vector occupies an important position in high school mathematics and has profound mathematical connotation. It not only injects vitality into the development of geometry, but also expands the research object of algebra[3], is the basis for further study and research in other areas of mathematics. In order to conform to the main line of "Geometry and Algebra" and play the role of vector as a tool to link geometry and algebra, the structure of the chapter "Plane Vector and Its Application" has been greatly changed in the new textbook.

Therefore, this paper chooses the chapter "Plane Vector and Its Application" and compares the new and old textbooks with ISM method, which will help math teachers to understand the changes in the arrangement system of "Plane Vector and Its Application", provide some reference for teachers' teaching and help teachers to carry out teaching activities efficiently.

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2. Research design

2.1. The research object

The research objects are Compulsory Mathematics Volume II (Version A) published by People's Education Publishing House in 2019 and Compulsory Mathematics 4 (Version A) published by People's Education Publishing House in 2004, focusing on the changing characteristics of the knowledge elements arrangement system in the chapter "Plane Vector and Its Application" in the two editions.

2.2. Research methods

2.2.1. ISM method

ISM method, the abbreviation of Interpretive Structural Modeling Method, was the earliest method to study the correlation structure analysis among complex elements in social system.[4]Using ISM method can sort out the disorderly knowledge elements into a clear hierarchical diagram, so ISM method is widely used in many fields.

2.2.2. Comparison of Teaching Materials Based on ISM Method

The comparative study of teaching materials based on ISM method can make the structure of teaching materials clearer, facilitate teachers to understand the changes in the arrangement structure of teaching materials and provide reference for teachers' teaching; It can also make the knowledge elements in the textbook and their forming relationships clearly presented in the form of visual graphics, which is helpful to help students clarify the relationship between the knowledge elements in the textbook and build a complete knowledge network system.

In 1978, Professor Ryubo Sato of Japan confirmed that ISM method is also suitable for teaching material development and target analysis.[5]Since then, more and more educational researchers have used this method in the field of education. For example, some educators in Australia have successfully applied ISM method to the classroom, which has benefited students in mastering the course content;[6]Vivek Chhetri applies ISM method to physics, which can help physics educators and decision makers plan strategies to improve undergraduate physics education.[7]

Domestic scholars' comparative study of textbooks based on ISM method can be divided into two categories. The most important one is the analysis of the knowledge structure of different versions of textbooks based on ISM method, and accordingly, teaching suggestions are put forward to provide reference for teachers' teaching design, involving disciplines such as geography, chemistry, biology and physics. For example, in 2018, Weng Jinna[8]ISM method is applied to the field of geography textbook comparison, which provides a new breakthrough point for the comparative study of geography textbooks. 2019, Wang Xin[9]The ISM method is used to compare and analyze American high school physics textbooks, which provides reference for the comparative study of Chinese and American textbooks. In the same year, Zhao ruolin[10]A comparative study on the logical structure of geography textbooks between China and the United States is carried out by ISM method. In 2020, Zhang Qunxi[11]Based on ISM method, this paper analyzes and compares the structure of high school biology textbooks between China and Britain, which has some enlightenment for the compilation of biology textbooks in China. In 2021, Song Qianwen[12]It is of great significance for teachers' teaching practice to make a comparative study of the knowledge structure of different versions of chemistry textbooks by ISM method. The other is based on ISM method to analyze the rationality of teaching sequence of textbooks. For example, in 2017, Yuan Yujuan and Xu Zhangtao[13] use ISM method to determine the teaching sequence of the compulsory series of senior high school mathematics in version A of People's Education, and provide some reference for the arrangement of teaching materials and the reasonable teaching sequence of teachers.

To sum up, the application of ISM method in the field of teaching material research has been relatively mature. Through the comparative study of teaching materials by ISM method, the arrangement structure of teaching materials can be presented in a clear hierarchical diagram form, and the changes of the arrangement structure of teaching materials can be clarified, so as to verify whether the arrangement of teaching materials is reasonable. The arrangement of plane vectors in current textbooks of various editions is controversial. The arrangement of plane vector chapters in the new textbook A of People's Education has changed greatly, and it is the most used textbook in China, which is very representative. Therefore, this paper chooses ISM method to explore the changes in the arrangement structure of the chapter "Plane Vector and its Application" in the old and new textbooks.

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2.2.3. ISM Textbooks Comparative Research Process

At present, using ISM method to study the structure of teaching materials mainly includes four steps (see Fig.1): First, extract knowledge elements; Second, determine the formation relationship between elements; Thirdly, establish adjacency matrix and calculate reachability matrix; Fourthly, draw a hierarchical directed graph, and analyze and discuss the hierarchical directed graph. If the discussion results are consistent, it is considered that the hierarchical directed graph is reasonable, and the operation flow is ended, otherwise, the first step or the second step is returned. Among them, the first step and the second step are the most important steps, which will directly affect the rationality of drawing hierarchical directed graph.

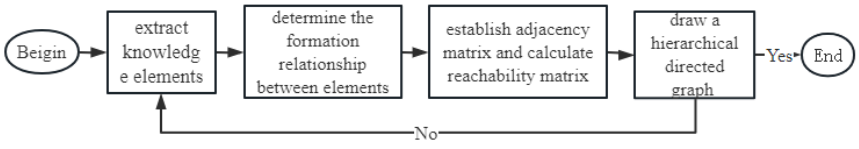

Figure 1: ISM method operation flow chart.

3. Research process

After analyzing the contents of "New Curriculum Standard", "Ordinary Senior High School Mathematics Curriculum Standard (Experiment)" and "Plane Vector and Its Application" in the old and new textbooks, the research is carried out according to the four steps of ISM method. Compare the changes in the selection of knowledge elements and the arrangement order of knowledge elements in this chapter between the old and new textbooks.

3.1. Extracting knowledge elements

Table 1: Knowledge Elements of "Plane Vector and Its Application" in New and Old Textbooks of People's Education Press.

encode	New textbook of people's education edition	Old textbooks of people's education edition
S_1	vectors	vectors
S_2	directed line segment	directed line segment
S_3	model	model
S_4	Basic vector	Basic vector
S_5	Vector addition operation	Vector addition operation
S_6	Inverse vector	Inverse vector
S_7	Subtraction operation of vector	Subtraction operation of vector
S_8	Multiplication of vectors	Multiplication of vectors
S_9	The judging theorem of plane vector collinearity	The judging theorem of plane vector collinearity
S_{10}	Quantity product	Basic theorem of plane vector
S_{11}	Projection and projection vector	Orthogonal decomposition
S_{12}	Operation of vector quantity product	Coordinate representation of vector
S_{13}	Basic theorem of plane vector	Coordinate operation of plane vector
S_{14}	Orthogonal decomposition	Coordinate representation of plane vector collinearity
S_{15}	Coordinate representation of vector	Quantity product
S_{16}	Coordinate representation of plane vector addition and subtraction operation	project
S_{17}	Coordinate representation of plane vector multiplication operation	Geometric significance of quantity product
S_{18}	Coordinate representation of plane vector collinearity	Operation of vector quantity product
S_{19}	Coordinate representation of plane vector quantity product	Coordinate representation of plane vector quantity product
S_{20}	Vertical coordinate representation of plane vector	Vertical coordinate representation of plane vector
S_{21}	Cosine formula of vector included angle	Cosine formula of vector included angle
S_{22}	Cosine theorem, sine theorem	

Every educational researcher has a different understanding of the core knowledge elements of

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mathematics textbooks, so the extraction of knowledge elements is influenced by subjective factors. Therefore, in order to ensure the rigor of teaching material research, when extracting knowledge elements, we should discuss with teaching researchers and front-line teachers in combination with the requirements of the New Curriculum Standard. The knowledge elements finally extracted meet the following four requirements: the main knowledge points required to be mastered by the system in the New Curriculum Standard; There must be a clear definition or knowledge point in the textbook, which must be taken as the main knowledge point in the teaching analysis summary of each class hour; In the whole chapter system, it has the function of connecting the preceding with the following; In order to simplify the calculation process, similar concepts are integrated into one concept. For example, zero vector, unit vector, parallel vector, equal vector, collinear vector, etc. are combined into basic vectors.[14]According to the above requirements, the knowledge elements in the chapter "Plane Vector and Its Application" in the new and old textbooks published by People's Education Press are extracted respectively, and numbered according to the order in which each element appears in the textbooks, such as Table 1 As shown.

3.2. Determine the formation of the relationship between the elements

After the knowledge elements are determined, it is necessary to further determine the formation relationship between the elements. Determining the forming relationship between elements is also interfered by subjective factors. Therefore, in order to minimize the interference of researchers in determining the forming relationship between knowledge elements, and taking into account the characteristics of learners and the arrangement logic of textbooks, this paper uses the following methods to determine the forming relationship between elements: firstly, according to the arrangement order of textbooks, if the concept of an upper element is formed, or the essential attributes of a lower element are used in the theorem derivation process, it can be determined that there is a forming relationship between these two elements.

According to the above regulations, after repeated revisions and discussions, the formation relationship diagram of new and old textbooks is drawn. Taking the new textbook as an example, the relationship between the knowledge elements is shown in Figure 2.

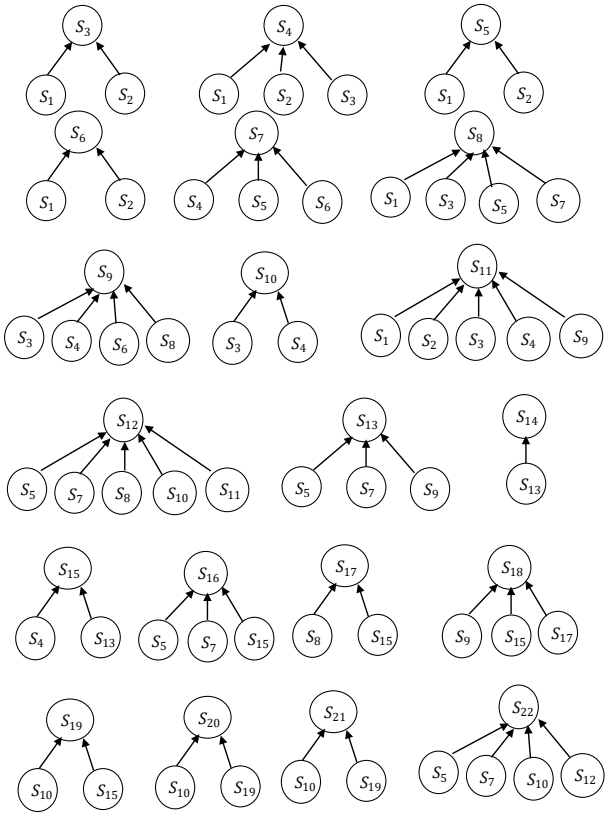

Figure 2: Relationship diagram of knowledge elements in new teaching materials.

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3.3. Establish adjacency matrix and calculate reachable matrix

After the formation relationship between knowledge elements is determined, the adjacency matrix can be obtained, and then the reachability matrix can be obtained. First of all, we should make a two-way form of elements according to the obtained formation relationship. Both the horizontal axis and the vertical axis in the table represent elements. If the expression or derivation of the elements on the horizontal axis in the textbook involves the elements on the vertical axis, then the intersection position of the two elements is "", otherwise, it is "". In order to avoid the table occupying a large space, this paper omits the relationship between some knowledge elements, such as the two-way formation of tables in new textbooks (Fig.3):

	S_1	S_2	S_3	S_4	S_5	S_6	⋯	⋯	S_{20}	S_{21}	S_{22}
S_1	0	0	1	1	1	1	⋯	⋯	0	0	0
S_2	0	0	1	1	1	1	⋯	⋯	0	0	0
S_3	0	0	0	1	0	0	⋯	⋯	0	0	0
S_4	0	0	0	0	0	0	⋯	⋯	0	0	0
S_5	0	0	0	0	0	0	⋯	⋯	0	0	1
S_6	0	0	0	0	0	0	⋯	⋯	0	0	0
…	…	…	…	…	…	…	…		…	…	…
…	…	…	…	…	…	…	…		…	…	…
S_{20}	0	0	0	0	0	0	⋯	⋯	0	0	0
S_{21}	0	0	0	0	0	0	⋯	⋯	0	0	0
S_{22}	0	0	0	0	0	0	⋯	⋯	0	0	0

Figure 3: The elements of the new textbook form a table in two directions.

Then, the two-way form of new and old textbook elements is transformed into adjacency matrix. The specific transformation principle is: if there are rows in the table, the adjacency matrix is the order, and the numbers in the table remain unchanged.$n * nn * n$

Finally, the adjacency matrix obtained from the transformation is programmed by MATLAB, and the reachable matrix is obtained. The reachability matrix indicates whether there is a connected path from one feature to another (ignoring the length of the path). The accessible matrix of the new textbook is recorded as R (Fig 4).

	1	0	1	1	1	1	⋯	⋯	1	1	1
	0	1	1	1	1	1	⋯	⋯	1	1	1
	0	0	1	1	0	0	⋯	⋯	1	1	1
	0	0	0	1	0	0	⋯	⋯	1	1	1
	0	0	0	0	1	0	⋯	⋯	1	1	1
R=	0	0	0	0	0	1	⋯	⋯	1	1	1
	…	…	…	…	…	…			…	…	…
	…	…	…	…	…	…			…	…	…
	0	0	0	0	0	0	⋯	⋯	1	0	0
	0	0	0	0	0	0	⋯	⋯	0	1	0
	0	0	0	0	0	0	⋯	⋯	0	0	1

Figure 4: Accessible matrix

3.4. Drawing hierarchical directed graph

According to the reachability matrix obtained in the previous step, the hierarchy of each knowledge element can be determined first. Taking the accessible matrix obtained from the new textbook of People's Education Press as an example, the accessible set of elements is, similarly, the antecedent set of elements is. Then, it is required that if it is stated that this element is located at the highest level, after determining the level of this element, this element will be pulled out of it, and then to see which element is satisfied, then the satisfied element will be regarded as the next level, and in this way, the lowest level element will be continuously searched. $S_1R(S_1) = \{1,3,4,5, \ldots,22\}S_1A(S_i) = \{1\}R(S_i) \cap A(S_i)R(S_i) \cap A(S_i) =$

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$R(S_i)R(S_i) \cap A(S_i) = R(S_i)$[15]Finally, the hierarchical relationship of knowledge elements between the old and new textbooks is obtained, as shown in Table 2.

Table 2: Hierarchical table of knowledge elements in new and old textbooks.

	New teaching materials	Old teaching materials
The tenth floor		S_{11},,,,,$S_{14}S_{17}S_{18}S_{20}S_{21}$
Ninth floor	S_{14},,,,,$S_{16}S_{18}S_{20}S_{21}S_{22}$	S_{13},,$S_{16}S_{19}$
Eighth floor	S_{12},,$S_{17}S_{19}$	S_{12},S_{15}
Seventh floor	S_{10},,$S_{11}S_{15}$	S_{10}
Sixth layer	S_9,S_{13}	S_9
Fifth floor	S_8	S_8
Fourth layer	S_7	S_7
Third layer	S_4,,S_5S_6	S_4,,S_5S_6
second floor	S_3	S_3
first floor	S_1,S_2	S_1,S_2

By Table 2, the hierarchical distribution table obtained by calculation, combined with the formation relationship diagram between the knowledge elements of the old and new textbooks obtained in the second step, which can draw the hierarchical directed diagram of the knowledge elements of the old and new textbooks, and on this basis, make many discussions and corrections, and finally get the hierarchical directed diagram of the knowledge elements of the old and new textbooks, see Fig. 5 and Fig. 6.

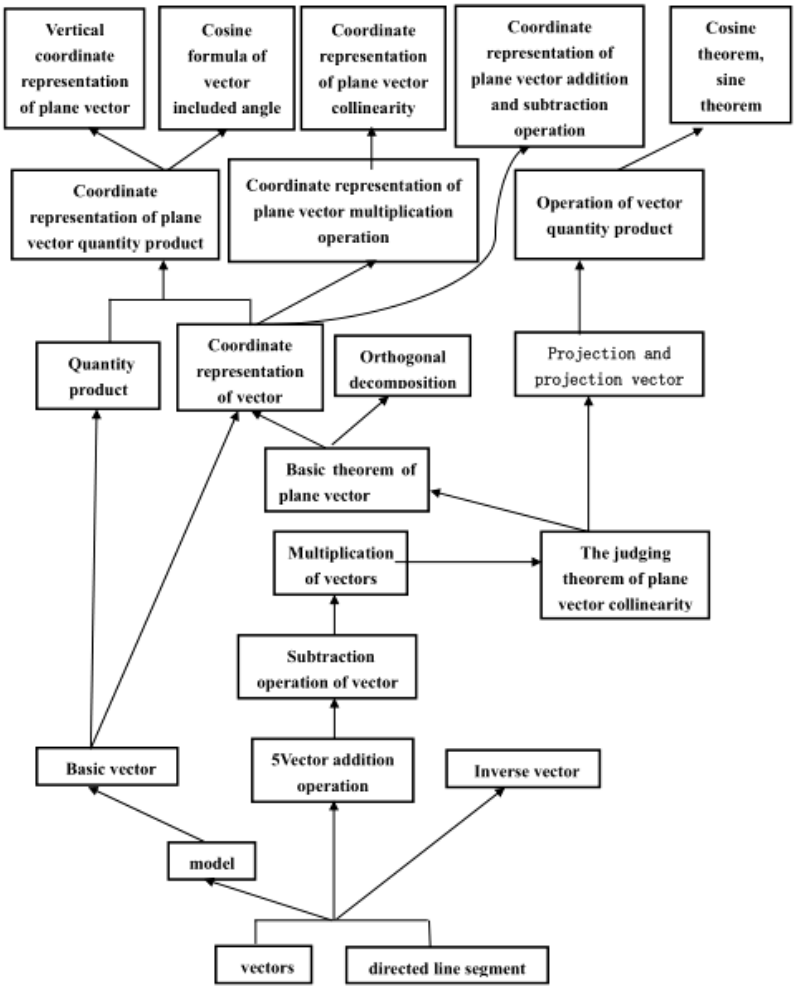

Figure 5: Hierarchical directed graph of new teaching materials.

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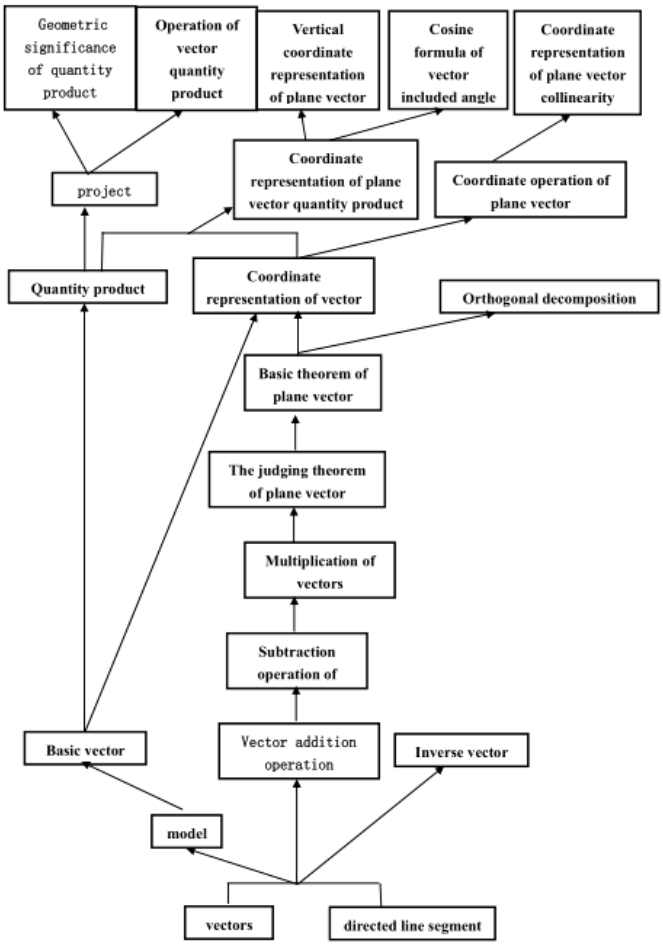

Figure 6: Hierarchical directed graph of old textbooks.

4. Changes in old and new textbooks

According to the research process of ISM analysis, the new and old textbooks are deeply analyzed and discussed from the following four aspects. Through analysis and discussion, it is helpful for textbook users to understand the changes of textbook arrangement structure of "plane vector and its application" and to understand the knowledge system of this chapter from a higher level.

4.1. Changes in the choice of knowledge elements

Comparing the coding table of knowledge elements of "Plane Vector and Its Application" in the new and old textbooks, it is found that some changes have taken place in the expression and selection of knowledge elements in the new textbooks. The new textbook changes the concept of vector "projection", and defines the projection of vector as a vector transformation rather than quantity. The new textbook supplements the concept of "projection vector" and makes an in-depth analysis of the concept. However, the new textbook does not clearly point out the "geometric meaning of quantity product". Secondly, the knowledge elements of "Sine Theorem and Cosine Theorem" are added to the new textbook, and the presentation order of theorems is adjusted, and the proof process of theorems is optimized by vector method.

4.2. The initial elements of the arrangement

The starting element is located at the first layer of the hierarchical directed graph, which is the basis for learning other superior elements. It can be seen from the hierarchical directed graph that the new and old textbooks have the same initial elements: "vector" and "directed line segment". From the hierarchical directed graph of the textbook, vector and directed line segment are the most basic knowledge points in this chapter. Only by clarifying the essential difference between vector and directed line segment can we

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further establish the vector operation system and start a systematic study of the contents of this chapter. Therefore, the new and old textbooks take vectors and directed line segments as the initial elements.

4.3. Changes in the arrangement of the highest elements

The highest element refers to the element at the highest level in the hierarchical directed graph, which is based on the learning of other knowledge elements. According to the hierarchical directed graph, the highest elements of the new and old textbooks are "coordinate representation of plane vectors collinear", "coordinate representation of plane vectors perpendicular" and "cosine formula of vector included angle". This is also very consistent with the arrangement order of knowledge elements in the old and new textbooks. The difference is that the highest elements of the new textbook are missing the geometric meaning of quantity product and the operation of vector quantity product, and adding the coordinate representation of plane vector addition and subtraction operation and cosine theorem and sine theorem. By analyzing the selection of knowledge elements in the old and new textbooks, we can find that the change of the highest elements in the new textbooks is well-founded. The new textbook omits the knowledge element "the geometric meaning of quantity product", but it does not reduce the breadth of knowledge, but analyzes the knowledge more carefully and thoroughly. The new textbook arranges the coordinate representation of plane vector addition and subtraction and the coordinate representation of plane vector multiplication respectively, while the old textbook combines these two knowledge elements into one knowledge element, the coordinate operation of plane vector. It can be seen that the definition of knowledge in the new textbook is clearer, and the knowledge points are presented one by one with clear logic.

4.4. Comparison of the relationship between knowledge elements and the textbook compilation system

The relationship between the knowledge elements of the old and new textbooks is basically the same, starting from the most basic concepts and theories, presenting the knowledge elements from simple to complex step by step, and constructing a knowledge structure framework of plane vectors with clear levels. Following the law of students' cognitive development also reflects the scientific nature of textbook compilation.

Influenced by the concept of compiling two editions of textbooks with different curriculum standards, the new textbooks have made great adjustments in the arrangement order and structure of knowledge elements. As for the operation of vectors, compared with the old textbooks, the operation of vectors is arranged in a decentralized way, that is, the linear operation of vectors is introduced first, then the basic theorem of plane vectors and their coordinate representation are introduced, and then the quantitative product of plane vectors and their coordinate representation are introduced.[16]In the new textbook, the operation of vectors is arranged centrally, and the coordinate representation of vector operation is also a systematic presentation, and the knowledge elements are naturally connected. The arrangement of the new textbooks emphasizes the integrity and systematicness of knowledge learning. With regard to the application of vectors, the main difference between the old and new textbooks is that the new textbook arranges the content of solving triangles in compulsory five of the old textbook in the section of the application of plane vectors, and adjusts the presentation order of theorems, and all of them are proved by vector method, which mainly reflects the systematization and structure of knowledge.

5. Conclusion and discussion

5.1. Conclusion

This paper mainly uses ISM method to deeply analyze the knowledge structure of "plane vector and its application" in the old and new textbooks of senior high school people's education edition. Get the following conclusions:

(1) The new textbooks pay more attention to the integrity of knowledge elements.

Judging from the choice of knowledge elements, the new textbook pays more attention to the integrity of all knowledge elements, the definition of knowledge elements is more rigorous, the presentation order of knowledge elements is more systematic and scientific, and the emphasis is on revealing the occurrence and development process of knowledge. For example, the revision of the concept of vector "projection" and the supplement of relevant knowledge of "projection vector" in the new textbook reflect the rigorous and scientific characteristics of the new textbook. In senior high school, there is a shadow of "projection

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vector" in many typical cases of applying vector method to solve mathematical problems. Understanding projection vector well plays an important role in grasping mathematical knowledge as a whole.[17]

(2) The new textbooks pay attention to the infiltration learning of the essential connotation of vectors.

From the arrangement of initial elements, the new and old textbooks point to the basic elements of this chapter in the same way. Both versions of the textbook pay attention to the construction of rich practical background of vectors and sort out the essential characteristics of vectors, which is beneficial to both teachers' teaching and students' understanding and mastery. "Addition operation of vectors" is the basic operation of vectors and the most direct embodiment of their essential attributes.[18]Judging from the compilation of "vector addition operation" in the old and new textbooks, the introduction of the new textbooks is straightforward and pays more attention to students' thinking about the essence of vectors.

(3) The new textbook fully highlights the instrumental role of vectors.

From the arrangement of the highest elements, both the old and new textbooks point to the vector as the research object of algebra. In particular, the highest elements of the new textbook add "cosine theorem and sine theorem", and further establish the connection between vector and triangle, which further highlights that vector is a powerful tool for the combination of numbers and shapes. This adjustment of the new textbook fully considers the internal relevance and systematicness of mathematical knowledge.[19]It conforms to the logical order and cognitive law of students' learning, and also helps students to form a complete knowledge network system and have a deeper understanding of the instrumental role of vectors.

(4) The arrangement system of new textbooks pays more attention to the systematicness of knowledge learning.

From the relationship between knowledge elements and textbook arrangement system, the main change between old and new textbooks lies in the difference of textbook arrangement system. From the hierarchical directed graph analysis, it can be seen that the arrangement structure of the old textbooks conforms to the logical structure of the knowledge system, and the order of knowledge elements appears from easy to difficult, spiraling up, following the students' cognitive laws. However, the curriculum structure is not systematic, the closely related contents are dismembered, and the main line of knowledge and mathematical thinking methods becomes blurred. The arrangement system of new textbooks pays more attention to the integrity of knowledge learning and meets the requirements of the New Curriculum Standard for textbook compilation. In addition, the new textbook pays attention to the relationship between mathematics and mathematics, and between mathematics and other disciplines, which is conducive to the improvement of students' overall quality; At the same time, the new textbook pays attention to the connection between mathematics and mathematical knowledge, integrates cosine theorem, sine theorem and plane vector, integrates knowledge context, and takes cultivating students' core literacy in mathematics as the main line.

5.2. Discussion

Based on the comparison and analysis of the new and old mathematics textbooks published by People's Education Press based on ISM method, we can find that the new textbooks pay more attention to the development of the core literacy of mathematics. The logical coherence of the structure system of mathematics textbooks has a fundamental impact on the implementation of core literacy.[20]From the hierarchical digraph of the old and new textbooks, we can see that the total number of levels of the old textbooks is one more than that of the new textbooks, and the hierarchical digraph of the old textbooks is in series, and the knowledge elements are in one-way connection, which lacks the cultivation and promotion of students' comprehensive ability; The relationship between knowledge elements in the new textbook is more complicated, which emphasizes the coherence of mathematical knowledge, and pays more attention to the cultivation of students' comprehensive ability and the improvement of overall quality. Therefore, in plane vector teaching, teachers should be clear about the changes in the content arrangement structure of this chapter and try to construct teaching methods and teaching concepts under the new situation. In the teaching process, students should be the main body, and inquiry and question-and-answer modules should be added, so that students can really participate in the classroom, mobilize the classroom learning atmosphere, and enhance their independent thinking ability and innovative spirit. Secondly, teachers should have a deep understanding of the knowledge system of plane vector, reserve solid knowledge, and pay attention to the cultivation of students' mathematical abstraction, intuitive imagination and logical reasoning ability in the teaching of plane vector. At the same time, teachers should take moral education as their fundamental task and implement educational policies and guidelines,

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not only focusing on broadening students' knowledge and promoting students' deep learning.

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