Research on Solving Trigonometric Problems in College Entrance Examination— Take the National 1/2/3 Volumes from 2018 to 2022 as an Example

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1. Introduction

Trigonometric functions are a cornerstone of high school mathematics and a key component of the National College Entrance Examination (Gaokao). Through analyzing trigonometric problems from the past five years National I/II/III Exam papers, Ive categorized these questions, examined relevant examples, and developed targeted problem-solving strategies. My research reveals the comprehensive difficulty levels and effective approaches for trigonometric questions in Gaokao exams, helping frontline teachers better understand assessment patterns, recognize their significance, and enhance instruction on core Gaokao topics. By categorizing trigonometric problems by knowledge points and providing tailored strategies based on exam complexity, this analysis aims to provide real-time teaching support for educators, ultimately developing adaptable lesson plans that boost students academic performance.

2. Methodology

2.1 Literature Research Method

Firstly, the research status of trigonometric functions is investigated by retrieving academic papers and journals, and then the data analysis and research are carried out; next, the personal existing data and research results are studied; finally, the trigonometric questions in national college entrance examination are analyzed, classified and summarized.

2.2 Statistical Analysis

This study compiles national college entrance examination papers (I/II/III) from 2018 to 2022. Through comparative analysis of question types, total questions, point values, and trigonometric function-related questions in liberal arts and science versions, the research employs visual charts to present findings with clarity. The paper analyzes trigonometric problem patterns and proposes targeted solving strategies. Using Bao Jianshengs Comprehensive Difficulty Model, it conducts statistical analysis on the difficulty distribution of trigonometric problems in the national exams.

This paper uses the comprehensive difficulty model modified by Wu Xiaopengs team to analyze the difficulty of trigonometric function questions in the new curriculum standard paper from six aspects, and calculates the difficulty

of the questions by using the coefficient formula [8].

2.3 Analytical Combination Method

This study analyzes the key points of trigonometric functions in Chinas National College Entrance Examination (Gaokao), compiling five years worth of frequently tested knowledge points and question types. Through detailed analysis of problem-solving procedures and techniques across various question types, we aim to accumulate practical experience. The research explores innovative teaching methods that enhance students understanding, application, and creative thinking in trigonometric functions [7].

3. Findings

Trigonometric functions hold significant weight in Chinas National College Entrance Examination (Gaokao), with diverse assessment points across various topics. By clarifying these key points and compiling them into a systematic framework, educators can better focus on essential knowledge areas while helping students effectively grasp and master core concepts.

3.1 Requirements of College Entrance Examination for Trigonometric Functions

3.1.1 Statistical statistics of the number of trigonometric function questions in the college entrance examination papers in the past five years

Combined with the bar chart, we can see that in the trigonometric function examination of the National College Entrance Examination, the national I, II and III papers mainly examine the knowledge of trigonometric functions through multiple choice questions, while the number of questions in fill-in-the-blank questions and subjective questions is nearly the same.

In the past five years college entrance exam papers, trigonometric function subjective questions have appeared 9 times. The key test points align with those of basic trigonometry problems, maintaining moderate difficulty overall. These typically cover three sub-topics: the sine/cosine theorem, trigonometric area formulas, and trigonometric transformations. As they rarely appear as challenging final questions, these questions generally serve as easy scoring

opportunities.

3.2 Statistical Analysis of the Score Ratio of Trigonometric Related Questions in Liberal Arts and Science

The data in Table 1 reveals that from 2018 to 2022, the trigonometric function section of the National College Entrance Examination (Gaokao) maintained nearly identical scoring weights between liberal arts and science streams. This demonstrates that trigonometric functions constitute a crucial subject area for both academic disciplines. To better analyze the differences and patterns in this sections performance across genders, I created vertical bar charts and horizontal pie charts respectively.
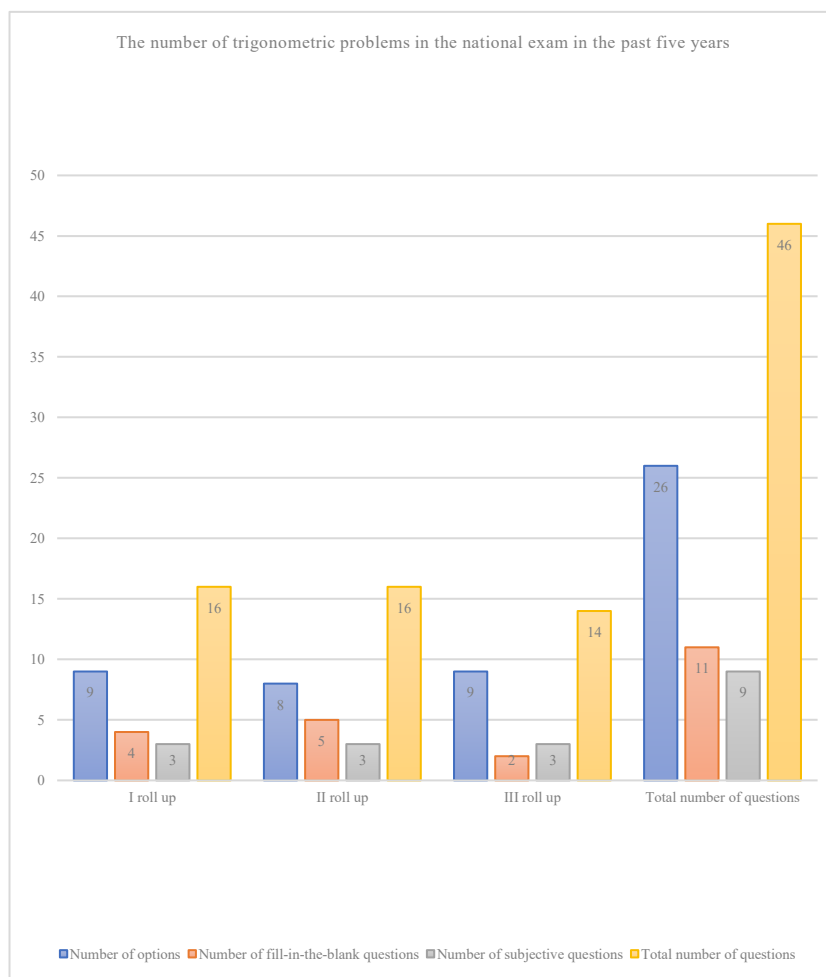

Figure 1: Statistics of the number of trigonometric functions in national exams in recent five years

Table 1: Statistics of the score ratio of trigonometric function related questions in arts and science

		2018	2019	2020	2021	2022	Cross-sectional statistics
National Paper I	liberal arts	10	32	17			59
	science	17	34	15			66
National Paper II	liberal arts	15	15	34			64
	science	15	15	34			64
National Paper III	liberal arts	10	17	15			42
	science	15	17	15			47
National Paper A	liberal arts				10	15	25
	science				10	25	35
National B paper	liberal arts				15	22	37
	science				20	22	42
Longitudinal statistics		82	130	130	55	84	481

Note: The blank part of the above table indicates that the volume was not used in that year.
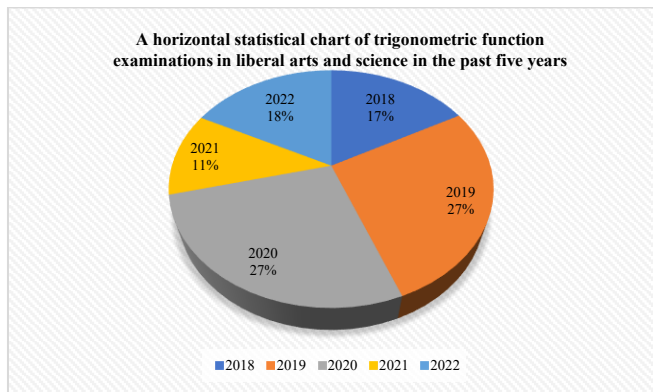
Figure 2: Vertical statistical chart of trigonometric function scores in liberal arts and science in the national college entrance examination in recent five years

Figure 3: Horizontal statistical chart of trigonometric function examination in liberal arts and science in college entrance examination in the past five years

Analysis: The longitudinal statistical chart reveals that trigonometric function questions in the National Paper I of

Chinas college entrance examination show the most significant score fluctuations. Notably, the 2019 National Paper I carried approximately twice the score value of the National Paper II and III combined, indicating these papers posed substantial challenges in trigonometry content. The National Paper II demonstrated a steady upward trend, with its 2020 score reaching 68 points – the highest in five years – highlighting trigonometric functions as the core focus. The National Paper III maintained stable scores with minimal fluctuations, covering comprehensive knowledge areas. Finally, the National Paper A and B followed an upward trajectory from 2021 to 2022, with scores gradually increasing. Projections suggest trigonometric function questions in 2023 will either rise or remain stable, requiring students to develop greater proficiency in related mathematical properties.

The horizontal statistical chart above reveals an upward trend in trigonometric question scores from 2018 to 2020, with continued growth observed in the 2021-2022 academic year. Combined with the vertical statistical data, this demonstrates that recent college entrance exams have increasingly emphasized trigonometric knowledge – a development both teachers and students should keep in mind.

3.3 Comprehensive Difficulty Analysis of Trigonometric Function Questions

I will utilize the comprehensive difficulty model developed by Wu Xiaopengs team to analyze Chinas National College Entrance Examination papers (I, II, III). While Wus team conducts holistic difficulty assessments of entire test papers, this study focuses specifically on trigonometric functions within the national exam. Accordingly, we have restructured the knowledge content classification by independent examination points rather than traditional unit-based knowledge categories. The model primarily evaluates six dimensions: contextual factors, computational proficiency, reasoning ability, knowledge depth, cognitive orientation, and cognitive level. [8], As shown in the table below.

Table 2: Analysis of trigonometric functions according to the difficulty of independent test points

Primary factor	Secondary factor	intension
Whether it contains a component	There are parameters	The test question contains operations with unknown parameters, including constant parameters and variable parameters
	No parameters	There are no relevant parameter operations in the test, all are numerical operations
Level of computing	Simple numerical operations	The operations in the test are conventional numerical operations, such as addition, subtraction, multiplication and division
	Re	The operations in the test are difficult and innovative
	Simple symbolic operations	The operation in the test includes simple mathematical and logical reasoning
	Complex symbolic operations	The operation in the test involves complex logical reasoning
inferential capability	Simple reasoning	The mathematical knowledge background involved in reasoning is relatively familiar, and the reasoning steps are less
	Complex reasoning	The mathematical knowledge background involved in reasoning is relatively complex, and the reasoning steps are more
Knowledge content	Single knowledge point	The test questions only include one knowledge point, which is divided by the independent test points
	Two knowledge points	The test questions only include two test points, which are divided by the independent test points
	greater than or equal to three	The test questions only include the test points of several knowledge points, which are divided by independent test points
Mental direction	Forward thinking	The solution is to solve the problem in a forward, direct way, following the order of existing knowledge
	reversed thinking	The solution is to solve the problem in reverse and indirectly according to the order of existing knowledge
Level of awareness	understand	The test is a direct examination of a certain knowledge point, only the understanding of the knowledge point can solve the problem
	utilize	The test questions are constructed through different mathematical situations on the basis of a certain knowledge, and belong to the application of knowledge
	analyse	There are many implicit conditions in the test, so we should analyze and comprehensively apply all the conditions of the problem to solve it

3.3.1 Parameter Level Factor Analysis

In comprehensive difficulty models, parameters play a crucial role in determining test item characteristics. These parameters fundamentally influence test difficulty levels. Parameter analysis is categorized into two types: non-parameter and parameterized. Parameterized test items involve both a single-letter variable and require computational operations to derive results. Non-parameter test items, conversely, either contain no parameters or use parameters solely for reference without requiring calculations, with the entire derivation process remaining entirely parameter-free [13]. Details are shown in Appendix Table 1.

(1) Difficulty factor analysis:

In the 2018 trigonometric function exam, all three test papers contained exactly the same number of questions. Each paper primarily featured non-parameter problems. Analysis of the five-year data shows that each of the 2018 test papers included exactly three questions, maintaining consistent question counts across all versions.

In the 2019 trigonometric function test, each of the five sets of papers had the same amount of questions on trigonometric function knowledge points; the main test background was parameter-based, and even accounted for 100% in Volume III.

Among the trigonometric function questions in the 2020 national college entrance examination, the second paper had the largest number of questions; the difficulty level of the test background was parameterized, while the other two papers had relatively stable number of questions.

In the trigonometric function questions in the 2021 college entrance examination, the difficulty level of each question is almost equal to that of parameter and non-parameter.

In the 2022 college entrance examination, the number of questions on trigonometric functions in paper A is the largest. Among the three papers, the number of questions without parameters is twice as many as that with parameters.

(2) Comprehensive analysis of parameter levels

Through comprehensive analysis of the data, we first observe that examination volumes in the same-year test papers remain remarkably consistent across all three versions, with many years maintaining identical numbers. This demonstrates a systematic correlation between the three test papers, allowing for predictable pattern recognition through question quantity analysis. Furthermore, trigonometric problems consistently appear as three questions annually. When major questions are introduced, corresponding reductions occur in multiple-choice and fill-in-the-blank sections. Given the alternating presentation of trigonometric problem types, this approach enables reliable prediction of question patterns in trigonometry assessments.

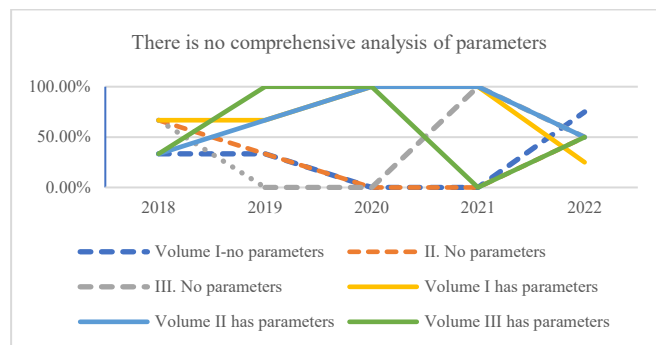I have drawn the data for the last five years into the following line chart:

Figure 4: Parameter level comprehensive analysis line chart

As can be seen from Figure 4, the three sets of test papers basically have more questions with parameters than questions without parameters. The line representing the level of no parameters on the line representing the level of parameters can be visually seen that the difficulty factor of trigonometric function questions in the college entrance examination is mainly the level of questions with parameters.

3.3.2 Comprehensive Analysis of Trigonometric Operation Level from 2018 to 2022

Through analyzing the annual exam papers, I discovered distinct patterns and trends in computational aspects. Specifically, trigonometric function problems primarily test symbolic operations, with a predominance of basic symbolic calculations. This aligns with our earlier analysis of parameters, demonstrating their complementary relationship.

The above data are drawn into the following statistical chart. However, due to the large number of factor levels, it will be very chaotic and inconvenient to observe and analyze in one statistical chart. Therefore, I draw three line graphs according to test paper I/II/III, as shown in Figure 5, 6 and 7.
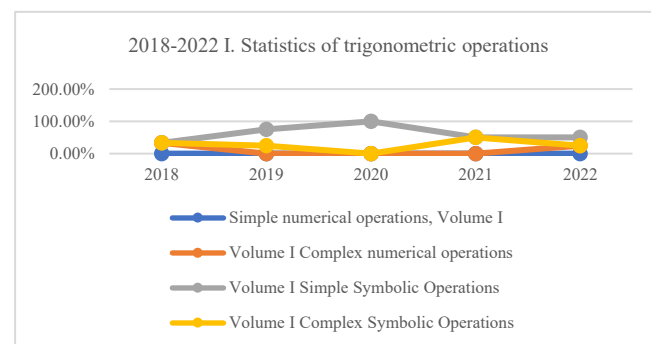

Figure 5: Statistical line chart of trigonometric operation level in Volume I from 2018 to 2022
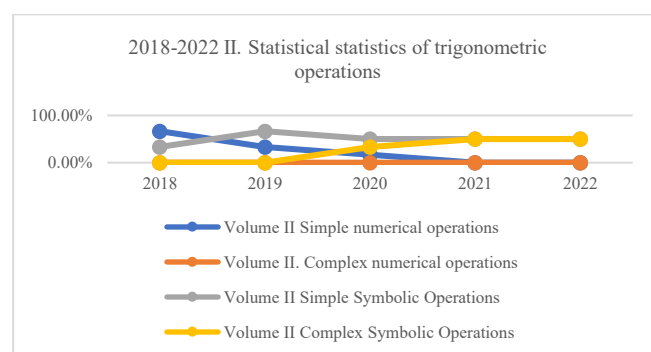

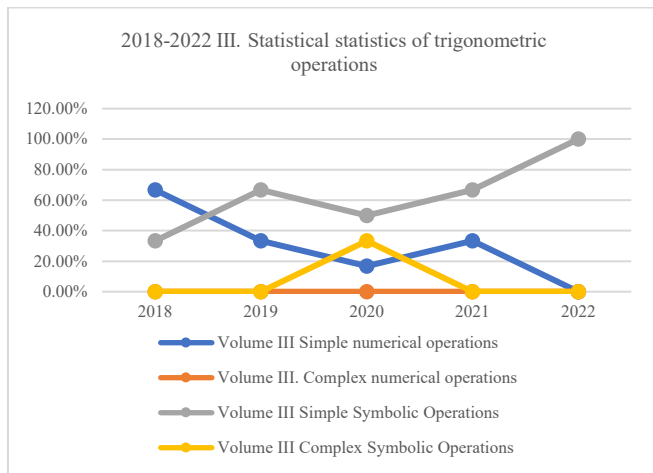**Figure 6:** Statistical line of trigonometric operation level in Volume II from 2018 to 2022

Figure 7: Statistical line chart of trigonometric operation level in Volume I, II and III from 2018 to 2022

The three line graphs reveal that the curve representing basic symbolic operations consistently stays above the baseline, indicating these operations form the primary focus across all test papers. The other curves demonstrate comparable wave patterns, suggesting that each set of exam papers maintains similar difficulty levels and distribution patterns in computational complexity.

4. Inferences Analysis

In this model, reasoning ability is divided into three levels: simple reasoning, general reasoning and complex reasoning. The division of the three is mainly based on the complexity of the questions and the reasoning steps.

4.1 Difficulty Analysis

In the trigonometric function test in 2018, simple reasoning test and complex reasoning test were basically the same, and each accounted for about 50%, so the reasoning level of the three sets of test was also similar.

In the 2019 trigonometric function test, the main question type is simple reasoning questions, which accounts for 66.70%. The distribution of reasoning questions in each set of test papers is similar.

In the three sets of papers in 2020, the main part is the questions of simple reasoning level. Although the number of questions in the three sets of papers is different, it can be seen from the whole that the questions of simple reasoning level are far more than those of complex reasoning level, and the difficulty of the paper is not large.

In 2021, the trigonometric function test questions are mainly simple reasoning questions, and overall, the trigonometric function is less investigated than other years.

In the 2022 trigonometric function test, simple reasoning and complex reasoning are equal, and the test is more difficult.

4.2 Comprehensive Analysis of Reasoning Ability in Trigonometric Function Test Questions from 2018 to 2022
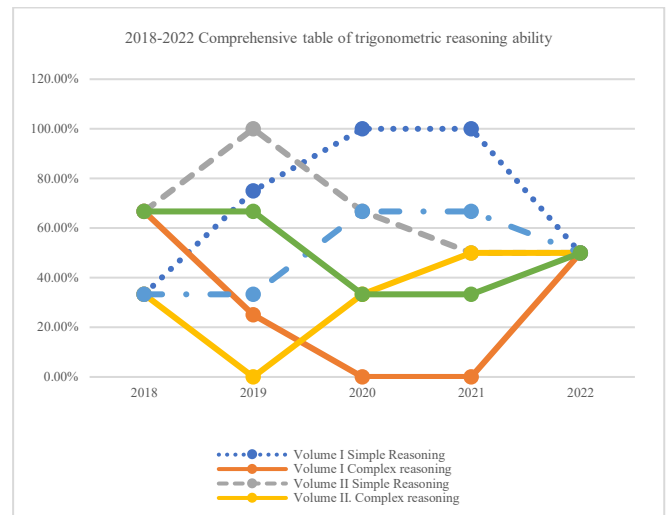

Figure 8: Comprehensive table of trigonometric function reasoning ability from 2018 to 2022

The analysis of the data reveals that in trigonometric function exam questions from the past five years, reasoning skills were predominantly assessed through basic reasoning levels, with complex reasoning questions constituting only a small portion. By compiling these statistics into a line graph, we can clearly observe that over most years, basic reasoning competencies consistently outperformed complex reasoning abilities.

5. Knowledge Content Analysis

Knowledge content refers to the comprehensive degree of the knowledge points contained in the question. Because it is about trigonometric functions, the knowledge of the trigonometric function system is calculated according to the summary of knowledge points, and the knowledge of other knowledge points is not counted.

Divide it into three levels by number: single knowledge point, two knowledge points, and more than or equal to three knowledge points[4].

5.1 Analysis of Difficulty Factors

In the 2018 test papers, the knowledge content of the three papers is one or two, the knowledge content of the three papers is relatively flat, and the knowledge content of the three papers is similar and stable.

In the 2019 papers, it can be found that the distribution of each type in the three papers is similar, except for the fact that there are three or more knowledge points in paper I.

In the 2020 test papers, it can be found that there is a big difference in the level of knowledge content among the three sets of test papers, and the proportion of the number of questions on a single knowledge point is relatively high in the second test paper.

In the 2021 trigonometric function test, the knowledge content level is relatively middle, and the distribution of knowledge content level in the two papers is similar.

In the trigonometric function test in 2022, there are more questions on two knowledge points, and the least questions on a single knowledge point.

5.2 Analysis of Knowledge Content of Trigonometric Function Test Questions from 2018 to 2022

I have compiled a line graph of trigonometric function questions from Chinas National Exam Papers (I/II/III) over the past five years. The analysis reveals three distinct patterns: single-subject questions show a downward trend, questions covering two subjects demonstrate significant fluctuations, while those involving three or more subjects maintain an upward trajectory.
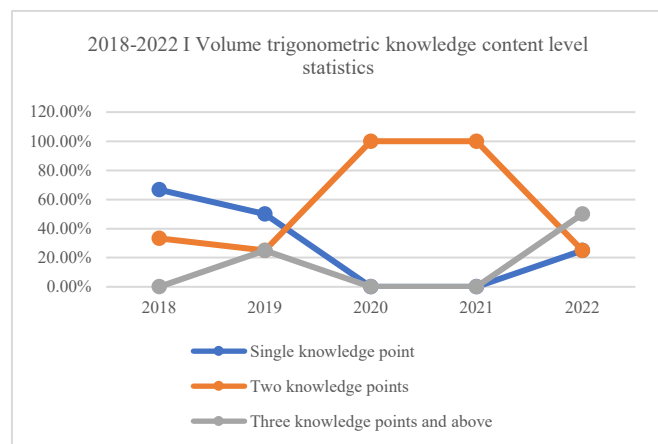

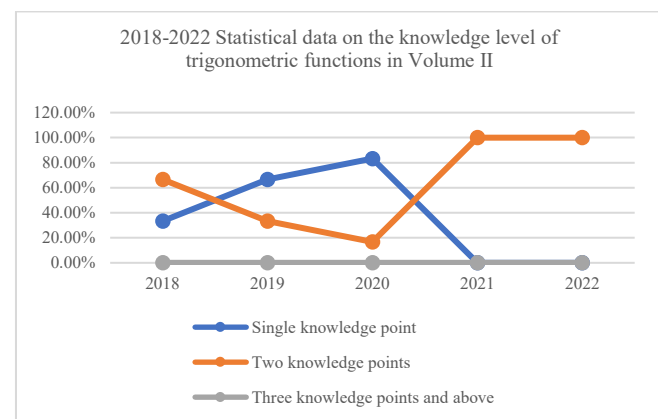**Figure 9:** Statistical data on the knowledge content level of trigonometric functions in Volume I from 2018 to 2022

Figure 10: Statistical statistics of trigonometric knowledge content level in Volume II from 2018 to 2022
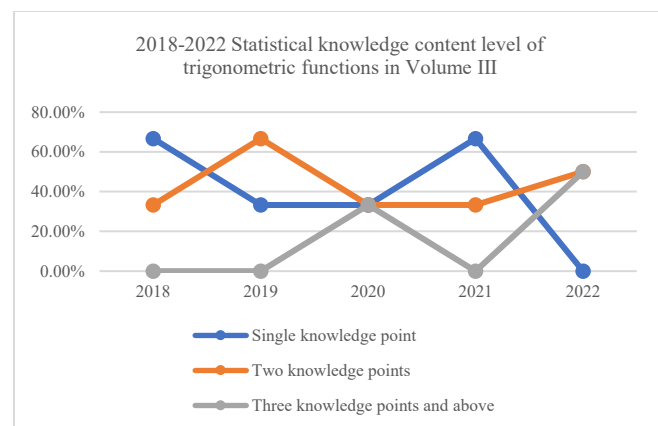

Figure 11: Statistical statistics of trigonometric knowledge content level in Volume III from 2018 to 2022

The three line charts reveal that questions on two core topics account for the majority of test items. This suggests these two areas will likely maintain their dominant position in coming years, while other question types are expected to see smaller proportions. The overall difficulty level of trigonometric function questions remains moderate. Students should focus on reinforcing their memorization of these key concepts to better prepare for exams.

6. Analysis of Thinking Directions

The direction of thinking refers to the application of knowledge points during problem-solving. The model categorizes this into two dimensions: forward thinking and reverse thinking. While forward thinking is relatively straightforward and easier to grasp, reverse thinking poses greater challenges for students as it requires thorough understanding of the knowledge points to complete the problem. Detailed data is provided in Appendix 5.

6.1 Difficulty Analysis

In the 2018 test, there were more questions of forward thinking than reverse thinking in each set of test papers. The overall difficulty was not too high.

In the 2019 test, there are 4 questions in the first paper, including 2 forward thinking and 2 reverse thinking, each accounting for 50%. The thinking difficulty of the test is relatively high, which will be more difficult for students. Therefore, the trigonometric function questions in the first paper are more difficult than the thinking difficulty of the second and third papers.

The 2020 exam papers demonstrated moderate cognitive difficulty. Overall, 90% of the questions were based on forward thinking, while reverse thinking was virtually absent. Among the three sets of papers released that year, the cognitive challenge level remained relatively low.

In the 2021 A and B papers, there are two questions every year, and each set of questions is one with forward thinking and one with reverse thinking. The difficulty level is relatively high, which makes it difficult for students to complete.

In 2022, the main thinking is forward, and overall, the thinking is up to 87.50%, so the overall difficulty is not very big.

6.2 Analysis of Thinking Direction of Trigonometric Function Test Questions from 2018 to 2022

Analysis of test papers from the past five years reveals that forward-thinking questions consistently outnumber reverse-thinking ones, with trigonometric function problems accounting for a larger proportion. By compiling these five-year data into a line graph, we can clearly observe that the forward-thinking curve remains consistently above the reverse-thinking curve.
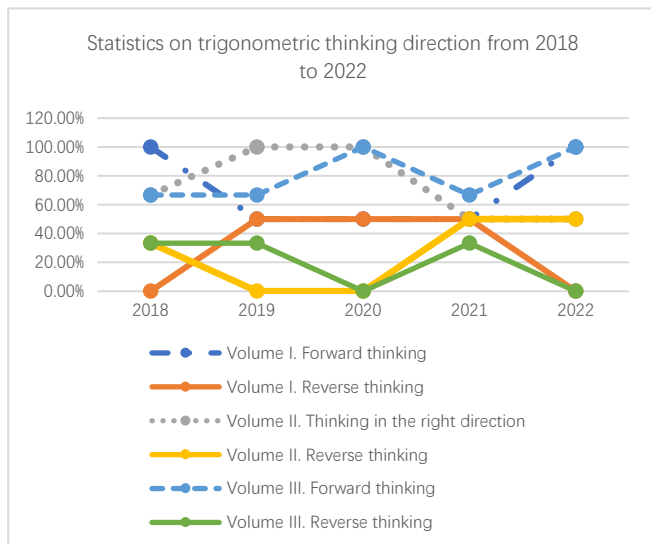
Figure 12: Statistics of trigonometric thinking direction from 2018 to 2022

7. Cognition Level Analysis

Cognition refers to the process of information processing in the process of problem solving. Cognitive level refers to the ability to process information [4]. In the model, it is divided into three levels: understanding, application and analysis. Detailed data are shown in Appendix 6.

7.1 Difficulty Analysis

In the trigonometric function test in 2018, the overall difficulty level distribution of the test paper is similar. In the first paper, there are more questions on understanding level, while in the second and third papers, there are more questions on application level.

In the trigonometric function test in 2019, the level distribution of the three papers was quite different, and the level of each paper was different.

In the 2020 trigonometric function test paper, the understanding level of trigonometric function questions accounted for a large proportion, and there was no analysis level test in the first and third volumes.

In the trigonometric function test in 2021, the application of cognitive level was relatively high, and the overall difficulty of the test was generally average.

In the trigonometric function test in 2022, the proportion of application level was relatively high, followed by analysis level, and the overall difficulty of the test was increased.

7.2 Comprehensive Analysis of the Cognitive Level of Trigonometric Function Test Questions from 2018 to 2022

Through the analysis above, we found that comprehension-level questions constituted the majority of test papers from 2018 to 2022. The statistical breakdown of question difficulty levels across Papers I/II/III is presented in the following graph. The line representing application-level questions shows a consistent dominance over other difficulty tiers throughout most years, indicating it remains the primary

assessment focus. Looking at the trend patterns, we anticipate an increase in cognitive-level questions in the future, which will place higher demands on students.
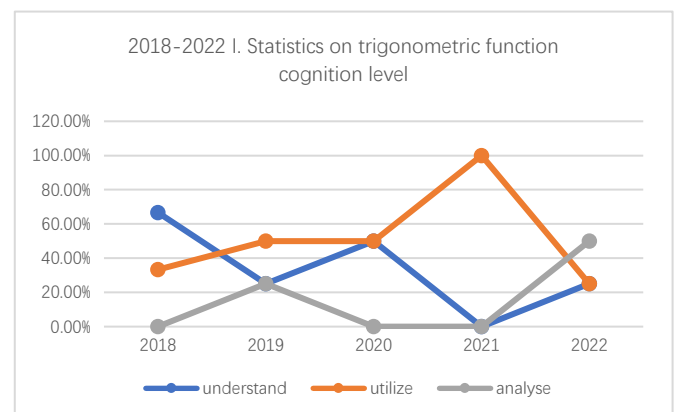

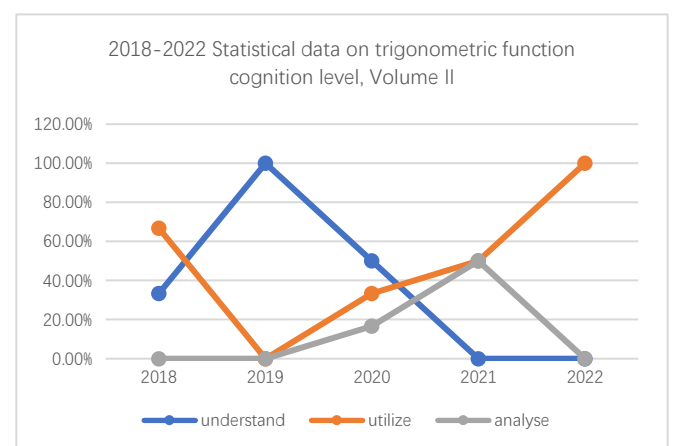**Figure 13:** Statistics of trigonometric function cognition level in Volume I from 2018 to 2022

Figure 14: Statistical statistics of trigonometric function cognition level in Volume II from 2018 to 2022
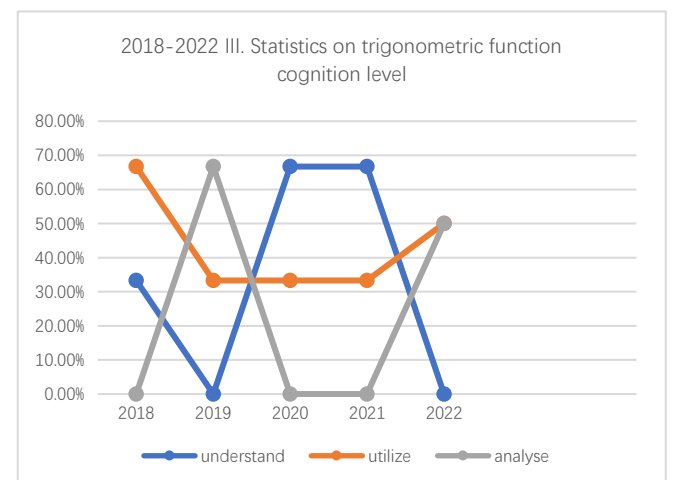

Figure 15: Statistical statistics of trigonometric function cognition level in Volume III from 2018 to 2022

8. Comprehensive Difficulty Analysis

According to the above data, I used the comprehensive difficulty model coefficient formula to conduct statistical analysis on the trigonometric function questions in the 2018-2022 college entrance examination I/II/III papers, and obtained the difficulty coefficients of each aspect. The following figure shows the weighted average of each

difficulty factor in the papers in the past five years.

Table 3: Comprehensive statistics of national math (science) test papers in the National College Entrance Examination in recent five years

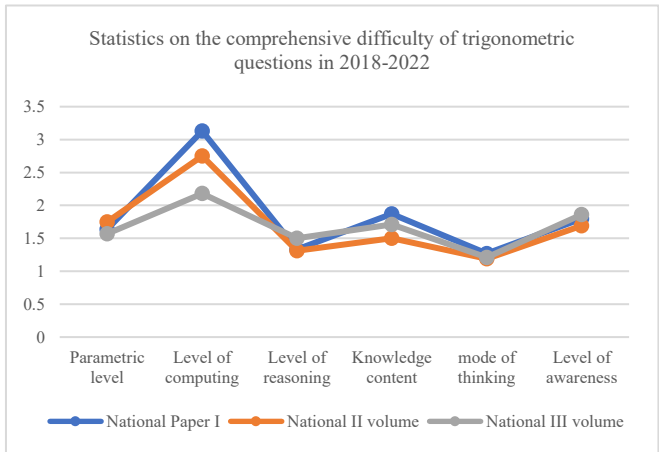| factor	horizontal	Number of questions			percentage			Overall difficulty coefficient		
		I roll up	II roll up	III roll up	I roll up	II roll up	III roll up	I roll up	II roll up	III roll up
Parametric level	No parameters	5	4	6	35.71%	25.00%	42.86%	1.64	1.75	1.57
	There are parameters	9	12	8	64.29%	75.00%	57.14%			
Level of computing	Simple numerical operations	0	4	5	0.00%	25.00%	29.41%	3.13	2.75	2.18
	Re杂数值运算	2	0	0	13.33%	0.00%	0.00%			
	Simple symbolic operations	9	8	10	60.00%	50.00%	58.82%			
	Complex symbolic operations	4	4	2	26.67%	25.00%	11.76%			
inferential capability	Simple reasoning	10	11	7	66.67%	68.75%	50.00%	1.33	1.31	1.50
	Complex reasoning	5	5	7	33.33%	31.25%	50.00%			
Knowledge content	Single knowledge point	5	8	6	33.33%	50.00%	42.86%	1.87	1.50	1.71
	Two knowledge points	7	8	6	46.67%	50.00%	42.86%			
	Three knowledge points and above	3	0	2	20.00%	0.00%	14.29%			
mode of thinking	Forward thinking	11	13	11	73.33%	81.25%	78.57%	1.27	1.19	1.21
	reversed thinking	4	3	3	26.67%	18.75%	21.43%			
Level of awareness	understand	5	7	5	33.33%	43.75%	35.71%	1.80	1.69	1.86
	utilize	8	7	6	53.33%	43.75%	42.86%			
	analyse	2	2	3	13.33%	12.50%	21.43%			

Figure 16: Statistical statistics of comprehensive difficulty of trigonometric function questions from 2018 to 2022

9. Difficulty Analysis

A careful observation of the figure shows that, among the six difficulty factors, the calculation difficulty coefficient of trigonometric function questions in the college entrance examination is the highest, and the thinking mode difficulty coefficient is the lowest.

In terms of computational skills, most exams focus on basic symbolic operations. The parameter-based questions reveal that trigonometric assessments emphasize symbolic manipulation. Since trigonometric functions are defined through angular symbols, they involve complex formulas like half-angle and double-angle formulas. With numerous function types and similar content patterns, mastering these formulas proves challenging. Even when students understand the quantitative relationships between variables like sine, cosine, and arctangent, they often encounter confusion when applying these formulas, leading to incomplete mastery.

In terms of reasoning level, simple reasoning is mainly examined, but it is not difficult to see that the reasoning ability of trigonometric problems tends to be complicated, and students have more difficulty in dealing with these problems.

In terms of knowledge content, it is not difficult to see that the difficulty score of each paper is above 1.5, so the trigonometric function test tends to be comprehensive, that is, it pays more attention to the combination of knowledge points.

In terms of thinking mode and cognitive level, it can be obviously found that they are relatively stable, and the variation between each test paper is not too big, with little volatility.

Project Fund

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Steps [J]. Teaching Reference for Secondary Schools, 2016.

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