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PROBABILITY AND STATISTICS QUESTIONS OF COLLEGE ENTRANCE EXAMINATION BASED ON MATHEMATICS CORE LITERACY -- A CASE STUDY OF COLLEGE ENTRANCE EXAMINATION MATHEMATICS IN RECENT FIVE YEARS (2019-2023) ACCOMPLISHMENT

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Abstract: This research is guided by the core mathematical competencies. Based on the national college entrance examination mathematics papers from 2019 to 2023, it adopts a research method combining quantitative and qualitative analysis to systematically analyze the probability and statistics questions. The analysis is carried out from four aspects: question - type structure, score distribution, knowledge dimension, and competency assessment, with a focus on examining the assessment characteristics and proposition trends of core competencies such as mathematical abstraction, logical reasoning, mathematical operation, and data analysis. The study finds that the probability and statistics questions in the college entrance examination exhibit the proposition characteristics of "real - life situations, structured thinking, and comprehensive methods". The score proportion of situation - based questions accounts for more than 65%. The questions emphasize the integrated assessment of mathematical modeling ability and statistical thinking, highlighting the integrity of the data analysis process and the rigor of logical reasoning. The research results have important reference value for optimizing the teaching strategies of probability and statistics and improving students' core mathematical competencies.
Keywords: Core mathematical competencies; College entrance examination mathematics; Probability and statistics questions; Proposition characteristics; Data analysis

1 INTRODUCTION

Probability theory [1] is a branch of mathematics that studies the quantitative laws of random phenomena, while statistics [2] is a science that uses the knowledge of probability theory to study how to reasonably obtain data and conduct data analysis. In high - school mathematics, without the foundation of advanced mathematics such as calculus and measure theory, it is impossible to give an axiomatic definition of probability and random variables. Therefore, high - school probability and statistics questions mainly focus on the assessment of basic concepts and knowledge such as classical probability models, geometric probability models, conditional probability, the distribution of random variables, range, expectation, and variance. In 2020, the Curriculum Standards for General High - School Mathematics were revised, proposing six core competencies for high - school mathematics. The six core competencies of high - school mathematics include mathematical abstraction, logical reasoning, mathematical modeling, mathematical operation, intuitive imagination, and data analysis. Core mathematical competencies [3] are the correct values, necessary character traits, and key abilities that students gradually develop through the study of mathematics. With the continuous deepening of the new curriculum reform, probability and statistics problems have gradually become a type of comprehensive problems that integrate the training of multiple competencies such as data analysis, mathematical abstraction, logical reasoning, and mathematical modeling.

Domestic scholars have conducted in - depth research on probability and statistics questions in the college entrance examination. Cao Yiming and Wang Wansong [4] used a combination of quantitative and qualitative analysis methods to study the probability and statistics content in the high - school mathematics curriculum standards of 15 countries including China, the United States, and the United Kingdom. Pan Yuchen et al. [5] obtained the main content of current and future statistical education research based on the research of *The International Handbook of Research in Statistics Education*. Wang Yu and Hu Fengjuan [6] studied the differences in curriculum standards and examinations of the statistics and probability parts in the college entrance examinations of China and the United Kingdom. Lin Yun [7] studied the cultural connotations and educational functions of probability and statistics courses from the perspectives of philosophy and culture. Li Yaqiong et al. studied the proposition characteristics of probability and statistics in the national new curriculum standards papers from 2011 - 2020 [8] and six new curriculum standards papers in 2021 [9] respectively. The research findings show that probability and statistics questions pay attention to the examination of basic knowledge.

The research emphasizes returning to textbooks and values the integration of probability with knowledge such as functions and sequences. The proportion of total scores for probability and statistics problems in the national examination papers shows an increasing trend. Ren Zichao, Chen Ang, etc. [10] analyzed and studied the quality of new

mathematics test papers in the college entrance examination after the new college entrance examination reform. Zhang Dingqiang and Pei Yang [11] took the national examination papers and Zhejiang examination papers from 2017 - 2018 as examples to study the consistency between mathematics test papers and the curriculum under the background of the new college entrance examination reform. Li Jiemin and Liao Yunzhang [12] pointed out that conditional probability is essentially a probability measure and put forward relevant suggestions for the teaching of this part. Liu Jianmei [13] studied the probability and statistics questions in the national examination papers from 2015 to 2019, and deeply explored the causes of errors, learning obstacles, and coping strategies for high - school probability and statistics questions. Ma Li [14] studied the laws and characteristics of probability and statistics questions in the national science mathematics paper I of the college entrance examination in the past 10 years. At the same time, she conducted a statistical study on the origin of the teaching materials to provide reference for the teaching of "probability and statistics". Li Qianqian [15] studied the probability and statistics questions in the college entrance examination in the past five years and carried out qualitative and quantitative analyses of the above - mentioned test papers according to the constructed evaluation framework of core mathematical competencies. Wang Hui [16] studied the implementation of logical reasoning competencies in the current teaching of high - school probability and statistics and explored its practical significance in teaching practice. Xie Peiyao [17] analyzed the probability and statistics questions in the college entrance examination mathematics from the perspective of core competencies using a combination of qualitative and quantitative methods. Zhang Deran and Mao Shisong [18] studied the teaching of probability and statistics from the perspective of cultivating students' awareness of random mathematical thinking, enabling students to understand that reasoning under random mathematical thinking is a combination of plausible reasoning and logical reasoning. Cheng Lingli [19] explored middle - school mathematics teachers' understanding and perception of probability concepts.

In conclusion, probability and statistics questions in the college entrance examination have become one of the contents in college entrance examination mathematics. The probability and statistics essay questions have become a very important type of comprehensive questions in college entrance examination mathematics. After the release of the new curriculum standards, the teaching of probability and statistics courses has received attention from a large number of middle - school mathematics teachers, which is conducive to improving students' core mathematical competencies such as data analysis, mathematical operation, and logical reasoning.

Based on the national and local examination papers from 2019 to 2023, this paper studies the probability and statistics question types in the college entrance examination mathematics papers in the past five years from five aspects: question - type design, score distribution, characteristics of knowledge points, core mathematical competencies, and proposition trends, so as to provide reference for the cultivation of high - school students' core mathematical competencies and teachers' teaching.

2 QUESTION TYPES AND SCORE ALLOCATION

Data analysis is one of the six core competencies in high - school mathematics. Since probability and statistics questions first appeared in the college entrance examination papers in 2000 and 2001 respectively, probability and statistics knowledge has become one of the compulsory contents in college entrance examination mathematics [8]. After more than twenty years of development, probability and statistics questions have entered the stage of innovation from the initial attempts and stability.

At present, probability and statistics questions in the college entrance examination cover all question types in college entrance examination mathematics: single - choice questions, multiple - choice questions, fill - in - the - blank questions, and problem - solving questions. Due to the incomplete explanation of probability and statistics knowledge in high - school mathematics, it is impossible to describe probability and statistics problems with an axiomatic mathematical system. Therefore, single - choice questions mainly assess the basic concepts and calculations of probability and statistics. Most of these types of questions are easy, but the last single - choice question may be a challenging one. It is mainly combined with permutations, combinations, independence, classical probability models, and geometric probability models for assessment. Multiple - choice questions mainly examine students' understanding of basic concepts, focusing on the application of probability. For example, in the multiple - choice question of probability and statistics in the 2023 New College Entrance Examination Volume II, the question is about the bit - error rate problem in the process of electronic signal transmission in the channel. The calculation of the bit - error rate is a practical probability problem often encountered in signal processing. This question mainly examines the application of probability knowledge. The scenario set in this question is the transmission of electronic signals, and the main knowledge points examined are the probability calculations of independent events and mutually exclusive events. This question has a strong practical application background. When doing this question, students are easily confused by the practical problem of signal transmission, which distracts their attention and increases the difficulty of the question.

Fill - in - the - blank questions are another important type of questions for examining probability and statistics in the college entrance examination. This type of question sets problems with specific application scenarios, increasing students' thinking about practical problems and affecting the accuracy of their answers. Probability and statistics problems mainly comprehensively examine classic probability models combined with knowledge such as permutations and combinations. For example, in the 2022 Zhejiang Volume, National Volume A, and National Volume B, the fill - in - the - blank questions in these papers mainly involve the classical probability model and its probability calculation. The fill - in - the - blank question in the 2022 Zhejiang Volume aims to examine students' calculations of probability and expectation. There are numbers written on 7 cards, and students need to calculate the probability of the classical

probability model by applying the frequency theory of probability according to the definition of random variables. One of the difficulties in this problem is calculating the probability of getting the number 2. At this time, it is necessary to conduct a classified discussion on the situation of getting the number 2: getting the number 2 once or twice. If the probability of getting the number 2 can be calculated, the probability of correctly solving this problem is relatively high. The National Volume A and Volume B in 2022 examine the frequency theory of probability, and the calculations of favorable events and total events are relatively simple. In conclusion, fill - in - the - blank questions in the college entrance examination of probability and statistics are mainly of medium and easy difficulty, and most of the questions examine the calculation of probability.

The problem - solving questions of probability and statistics are a type of questions that have been continuously innovating in recent years. This type of question can be regarded as the extension of application questions and mathematical modeling to random problems. From a historical perspective, the test papers before 2010 mainly focused on classical probability calculations and simple applications. Judging from the probability and statistics questions in the college entrance examination mathematics from 2019 to 2023, this type of question will be comprehensively examined in combination with functions, sequences, and other problems. In the 2021 New College Entrance Examination Volume II, the question is a probability model of microbial population reproduction, which is a classic example of the application of probability in ecology or biology. It is also the application of probability and statistics in survival analysis, preparing students for learning more complex probability models such as survival models in the future. In this problem, probability needs to be applied to sequences and functions, which is a comprehensive question involving probability, sequences, the monotonicity and extreme values of functions. The third question of this problem is an open - ended subjective question, examining students' abilities of logical reasoning and plausible reasoning. As long as students write a reasonable answer, it is correct. This question breaks the tradition that the answer to a math problem is unique and well examines students' comprehensive qualities, which is a major change in college entrance examination math questions. Judging from the problem - solving questions in college entrance examination mathematics from 2019 to 2023, problems are mainly set in combination with certain scenarios to solve relevant probabilities, or combined with actual data to examine students' mastery of probability and statistics knowledge such as frequency distribution tables, random sampling, and classical probability.

Since 2023, the college entrance examination is mainly divided into the national unified proposition and the separate proposition of some provinces. The types of test papers used in the national college entrance examination are divided into five categories, including the National Volume A, National Volume B, New College Entrance Examination Volume I (New Curriculum Standard Volume I), New College Entrance Examination Volume II (New Curriculum Standard Volume II), and Self - proposition Volume. The provinces with self - proposition are Beijing, Tianjin, Shanghai, and Zhejiang. The following table shows the score distribution of some probability and statistics questions in the college entrance examination in China in the past five years.

Table 1 Statistical Table of Scores of Probability and Statistics in College Entrance Examination Mathematics in the Past Five Years

Year type	Single choice	Multiple choice	Gap filling	Response question	Collect
2023 Shanghai	4			16	20
2023 National II volume		5		12	17
2023 National volume I		5		12	17
2023 Beijing				14	14
2023 Tianjin	5		5		10
2023 National first division	5			12	17
2023 National A text	5			12	17
2023 National B	5			12	17
2023 National Ewen	5			12	17
2022 Zhejiang			6		6
2022 National Volume II	5			12	17

Table 1 statistically analyzes the score situations of probability and statistics in a total of 11 college entrance examination papers from 2022 to 2023. From Table 1, it can be concluded that the average score of probability and statistics questions in these 11 college entrance examination papers is 15.3 points, and both the median and the mode are 17 points. The college entrance examination paper with the highest score for probability and statistics questions is the 2023 Shanghai paper. The score of the problem - solving question in this paper is 16 points, which is higher than that of other papers. While the paper with the lowest score is the 2022 Zhejiang paper. There is no problem - solving question in the probability and statistics questions of this paper. There is only one fill - in - the - blank question with a score of 6 points. Next is the 2023 Beijing paper, which only has 10 points and only includes multiple - choice and fill - in - the - blank questions. Except for the above two papers, the other 9 papers all have one problem - solving question, with an average score and a mode of 17 points. From the above analysis, it can be seen that the college entrance

examination questions of probability and statistics mainly focus on problem - solving questions, with a score of around 17 points. At the same time, there are relatively few probability and statistics questions in the college entrance examination papers of Zhejiang and Tianjin, with scores of around 10 points.

3 KNOWLEDGE POINTS OF PROBABILITY AND STATISTICS IN THE COLLEGE ENTRANCE EXAMINATION

The study of elementary probability theory can be divided into two learning stages at different levels. The first stage involves learning about discrete random variables with probability mass functions and continuous random variables with density functions. The second stage is about learning axiomatic probability theory based on measure theory. At the high - school level, students have not delved deeply into knowledge of single - variable calculus and multi - variable calculus, let alone real - variable functions and measure theory. Therefore, the knowledge of probability and statistics in high school mainly focuses on the frequency perspective of probability, which belongs to the first - stage elementary probability theory.

Based on the analysis of 81 probability and statistics questions from 2019 to 2023, the following conclusions can be drawn: The main assessment contents of probability and statistics in the college entrance examination mainly include probability calculations combined with classical and geometric probability models, permutations and combinations, independence and independence tests, descriptive statistical analysis of data, and the calculation and application of probability.

The most frequently examined knowledge points in the college - entrance - examination probability and statistics papers are probability calculation and its application, as well as the calculation of classical and geometric probability models. In the college - entrance - examination mathematics questions from 2019 to 2023, there were 43 questions related to probability calculation and its application. Among them, there were 15 multiple - choice questions, 12 fill - in - the - blank questions, and 17 problem - solving questions. The 2020 New Curriculum Standard II Science paper set a question with the random change in the number of online orders in a supermarket during the COVID - 19 prevention and control period as the context. The number of newly added orders each day is a random variable. This question was closely related to current political hotspots, using the COVID - 19 prevention and control situation as the context. The question was novel in design and ingeniously conceived. Students were required to abstract a probability model from real - life situations and solve it using probability methods. By analyzing the college - entrance - examination mathematics papers in the past five years, it can be concluded that the application questions of probability and statistics are set based on real - life scenarios. Students need to understand the essence of random variables in real - life and perform calculations. Since high - school students have not deeply studied relevant knowledge of calculus and measure theory, probability and statistics questions can only be set from the frequency perspective. Therefore, common assessment contents involve classical and geometric probability models. From the college - entrance - examination questions studied in this paper, there were 12 multiple - choice questions, 7 fill - in - the - blank questions, and 11 problem - solving questions related to classical and geometric probability models.

Descriptive analysis of data is a frequently - tested knowledge point in the statistics part of the college entrance examination. It mainly includes contents such as mode, median, mean, estimating the population distribution from the sample frequency distribution, and frequency distribution histograms. For this part of the content, as long as students master the basic concepts and apply the statistical calculation formulas, they can solve the problems. These are mostly medium - difficulty and easy questions. Independence test is also a frequently - tested content in statistics, mainly in the form of problem - solving questions. In the college - entrance - examination questions studied in this paper, there were a total of 14 problem - solving questions. There were almost annual questions on the knowledge point of independence test, which requires high - school teachers to strengthen teaching in this regard.

From the above analysis, it can be seen that the main knowledge points examined in probability and statistics in the college - entrance - examination mathematics are the calculation and application of probability in real life, as well as data analysis and its practical significance. This is mainly reflected in the probability calculations of classical and geometric probability models.

4 CORE MATHEMATICAL COMPETENCIES

From the probability and statistics questions in the college entrance examination over the past five years, the main characteristics of the assessment of core mathematical competencies can be summarized as follows: First, it emphasizes the assessment of multiple core mathematical competencies, strengthening the comprehensiveness of college entrance examination propositions. Second, it attaches importance to the creation of scenarios, which are closer to social hot - topics and feature more refined and realistic models. Third, the questions are more open - ended, with progressive inquiries, making them more exploratory.

The probability and statistics questions in the college entrance examination all involve the assessment of multiple core mathematical competencies, among which data analysis, mathematical abstraction, logical reasoning, and mathematical operation are frequently examined. For example, the probability and statistics problem - solving question in the 2023 Beijing paper is about studying the price change pattern of a certain agricultural product. A total of 40 consecutive days of price data of this agricultural product were collected. This question examines students' data analysis ability. When describing price changes, “+” is used to represent “increase” and “ - ” is used to represent “decrease”, which is an

example of mathematical abstraction. Calculating the probability of the price increase of this type of agricultural product based on past data and estimating the probabilities of price increase and decrease of this agricultural product test students' mathematical operation ability. This is a typical question that assesses multiple core mathematical competencies. To analyze the price change situation of this agricultural product, reasoning based on the existing data is also required. This is a form of reasoning under random mathematical thinking, which is a combination of plausible reasoning and logical reasoning [18].

Scenarios related to social hot - topics are set to examine students' comprehensive analysis ability. The scenarios set in the 2020 New Curriculum Standard II Science paper and the 2021 Beijing paper are about epidemic prevention and control during the COVID - 19 period. The 2020 New Curriculum Standard II Science problem - solving question is about the processing of online orders during the epidemic prevention and control period. During this period, to prevent cross - infection, people generally placed online orders for goods. This question sets up a problem of random order volume distribution based on this scenario. The new orders on the second day are random variables, and their magnitudes need to be inferred based on past data. It is a comprehensive problem of probability and statistics. The 2021 Beijing paper sets the scenario of the mixed - testing method in nucleic acid testing. When medical staff are in short supply, mixed sampling can significantly reduce the burden on medical staff, but its scientific nature needs to be verified. This question examines the “k - in - 1 testing method” to conduct a theoretical study on mixed sampling. This type of question is closer to real life and belongs to the category of social - hot - topic scenarios.

The question types of probability and statistics in the college entrance examination are more open - ended and flexible to answer. The probability and statistics question in the 2022 National Volume B is about environmental governance. By randomly selecting 10 trees, their cross - sectional areas and volumes are counted. The cross - sectional areas and volumes of the roots of this type of tree and their correlation coefficients are estimated. The third question also requires calculating the total volume of this type of tree. This question is more comprehensive than traditional math questions, as it needs to consider statistics, probability, and the actual situation of tree growth. It requires the comprehensive application of logical reasoning and plausible reasoning. Such questions are more open - ended. Students need to conduct plausible and logical reasoning on random problems. The second question is the probability and statistics problem - solving question in the 2023 Beijing paper: “The price change pattern of a certain agricultural product”. The scenario of this question is newly set, and the answer is flexible, showing more flexible openness. In the third question, students can find the price change situation of the agricultural product according to their own statistical methods and draw relevant conclusions based on plausible reasoning. This changes the previous situation where math questions had a single answer, representing a breakthrough change in college entrance examination math proposition.

5 PROPOSITION TRENDS

This paper studies a total of 81 college entrance examination questions on probability and statistics nationwide from 2019 to 2023. These questions feature novel scenario settings and strong comprehensiveness. In summary, the probability and statistics questions in the college entrance examination have the following characteristics:

5.1 Comprehensive Examination, Returning to Basics

Analysis of the probability and statistics papers in the college entrance examination mathematics over the past five years shows that the examination attaches great importance to basic knowledge and covers a wide range. The main knowledge points in the college entrance examination of probability and statistics include: mutually exclusive events and opposite events, classical probability models, geometric probability models, conditional probability, independence of random events, normal distribution, independence test, descriptive statistical analysis (mode, median, mean, correlation coefficient, variance, etc. of statistical data), and estimating the overall distribution from the sample frequency distribution. The probability and statistics questions in the college entrance examination mainly test the basic concepts of probability and statistics and their calculation methods, highlighting the fundamentals. Classical probability models and geometric probability models appear repeatedly, and key content generally appears in the major questions, which fully reflects the requirements of the mathematics college entrance examination: "Core knowledge is examined repeatedly, and key knowledge is examined with emphasis."

5.2 Strong Comprehensiveness, Reflecting Core Mathematical Competencies

The probability and statistics questions in the college entrance examination assess multiple core mathematical competencies, such as logical reasoning, data analysis, mathematical abstraction, and mathematical operation, fully demonstrating the comprehensiveness of the college entrance examination mathematics papers. Through statistical analysis of the types of probability and statistics questions in the college entrance examination over the past five years, it can be found that the mathematical operation competency has the highest proportion in each year's examination. Next are logical reasoning and data analysis. Judging from the college entrance examination mathematics papers across the country in 2023, flexible logical reasoning and plausible reasoning are required.

5.3 Stable with Changes, Focusing on Innovation

Judging from the probability and statistics questions in the college entrance examination over the past five years, the calculation and analysis of probability are the contents every year. The most important thing in probability and statistics is to find the inherent laws from the random changes of things. Therefore, probability calculation is bound to become an essential part of the college entrance examination mathematics. However, the proposition scenarios and questions are constantly innovating. Every year, it keeps up with the hot topics of the times and innovates continuously. For example: COVID - 19 pandemic, Asian Games, environmental governance, etc. In terms of questions, there are more and more open - ended questions, requiring students to have a deeper understanding of real - life problems.

COMPETING INTERESTS

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