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Analysis and Measures of Cognitive Barriers in Mathematics in High School

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Abstract: This article aims to analyze the current situation and causes of high school mathematics cognitive barriers in the United States, and to put forward practical measures to solve the problem, aiming to provide lessons and references for improving high school mathematics education in the United States. The article first analyzes the specific manifestations of high school mathematics barriers from three aspects: conceptual understanding barriers, data processing and analysis barriers, and insufficient abstract thinking and logical thinking skills, and then explores the solution measures. The analysis found that the problem of high school mathematics cognitive impairment is a long-term and arduous task, and comprehensive measures should be taken to cope with the problem of high school mathematics cognitive impairment from multiple perspectives.

Keywords: High school mathematics; Cognitive impairment; Computational analysis

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1. Introduction

In today's globalized educational environment, the quality and effectiveness of high school mathematics education in the United States have been in the spotlight as an important part of fostering young people's logical thinking, problem-solving skills, and scientific spirit. However, in recent years, more and more students are facing the problem of cognitive disabilities in mathematics, which not only affects their academic performance but also hinders their development in their future careers. Therefore, it is of great significance to analyze the cognitive impairment in mathematics in American high schools in depth and propose targeted measures to solve the problem to improve the quality of mathematics education in American high schools and promote the overall development of students. Mathematical cognitive barriers refer to the cognitive difficulties encountered by students in the process of mathematics learning. In the United States, the cognitive barriers in mathematics faced by students may be unique due to the influence of various factors such as cultural background and educational system. Therefore, it is necessary to study the manifestations of mathematics cognitive barriers and measures to address them in American high schools.

2. Types of mathematical cognitive impairment and their impact on students' learning

Mathematical cognitive disorders refer to students' significant difficulties in processing mathematical information, forming mathematical concepts, mastering mathematical methods, or solving mathematical problems in the process of mathematical learning due to the limitations of certain psychological or physiological factors. These barriers may originate from students' deficiencies in attention, memory, logical thinking, spatial perception, and other abilities, or they may be related to factors such as students' learning habits, interest motivation, or emotional state [1–2].

2.1. Effects of cognitive impairment in mathematics on students

2.1.1. Impact on learning

Due to their inability to effectively understand and apply mathematical knowledge, students' cognitive impairment often leads them to perform poorly in math exams, which in turn affects their overall academic performance. Secondly, in the face of difficulties and frustrations in learning mathematics, students may gradually lose their interest and enthusiasm in mathematics, or even develop an aversion to learning. In addition, long-term difficulties in mathematics may make students feel inferior and helpless, thus reducing their self-confidence and motivation to learn other subjects [3].

2.1.2. Reduced self-efficacy

Cognitive impairment in mathematics can also lead to a decrease in students' self-efficacy. Self-efficacy refers to an individual's evaluation of his or her ability and confidence in accomplishing a task or activity. In mathematics learning, due to the inability to effectively master knowledge and skills, students will gradually doubt their ability in mathematics and believe that they are unable to achieve good grades or make progress. This reduced self-efficacy will further affect students' motivation and effort in learning, forming a vicious circle [4].

2.2. Diversity of types of cognitive impairment

The types of cognitive impairment in mathematics are diverse, and different students may exhibit different characteristics of the impairment, and the common types of cognitive impairment are shown in **Table 1**.

Table 1. Common types of cognitive impairment

Types of cognitive disorders	Manifestations
Language-based disorders	Difficulty in understanding mathematical terms, formulas, or definitions and in expressing and communicating in the language of mathematics [5].
Numerical disorders	It is prone to errors in the calculation process and cannot perform numerical or symbolic operations accurately [6].
Logical disorders	Lack of logical reasoning skills in solving math problems and difficulty in developing effective ideas and methods for solving problems.

3. Specific manifestations of cognitive impairment in mathematics in American high schools

3.1. Conceptual understanding barriers

In the process of learning mathematics in American high schools, students' barrier to understanding statistical concepts is a common problem. This barrier is mainly manifested in the following aspects. Firstly, students often confuse the basic terms and concepts in statistics, such as mean, median, plurality, variance, and so on. They may not be able to accurately understand the definitions and calculations of these concepts, leading to errors in analyzing and interpreting data. Secondly, students often do not have a deep enough understanding of probability and probability distributions. They may have difficulty understanding the uncertainty of random events and the role of probability in statistical inference, which directly affects their application of advanced statistical methods such as hypothesis testing and confidence intervals. In addition, students tend to view concepts and methods in statistics in isolation and cannot link them together to form a holistic view. This makes it difficult for them to analyze and solve complex statistical problems by applying what they have learned in an integrated way.

3.2. Barriers to data processing and analysis

Barriers to data handling and analysis in statistics in American high school mathematics are a complex and multifaceted problem. When handling data, students may encounter difficulties in understanding data collection methods, data cleaning, data organization, and data interpretation. At the same time, when analyzing data, they may have difficulty in selecting and applying appropriate statistical methods or in effectively interpreting the results of their analyses. Specifically, barriers to data handling and analysis are manifested in a lack of in-depth understanding of the sources, structure, and meaning of data; or when organizing data into a form suitable for analysis, students may be confused because they are unfamiliar with data transformation or integration techniques; or they may not be able to select the appropriate statistical methods according to the nature of the problem, resulting in inaccurate results or inability to draw valid conclusions.

3.3. Insufficient abstract thinking and logical thinking skills

In the learning process of high school mathematics, the cognitive barriers of insufficient abstract thinking and logical thinking ability are also often faced. These barriers are especially obvious in mathematical computation, which can be summarized into two main aspects. On the one hand, the difficulty of understanding abstract concepts [7]. Mathematics is full of abstract concepts such as functions, vectors, limits, and so on, which are often far from daily intuitive experience and require students to think deeply and understand. However, it is often difficult to accurately grasp the essence of these concepts due to insufficient abstract thinking skills. For example, when learning the concept of function, they may not be able to understand function as a special kind of correspondence, but simply regard it as a kind of arithmetic rule, leading to difficulties in the subsequent learning of the properties and images of functions. Similarly, when learning the concept of vectors, one may not be able to grasp the directionality and magnitude of vectors, leading to errors in vector operations and vector applications. On the other hand, it is not possible to construct logical chains effectively. Mathematics is a highly logical subject, and the solution to many problems requires rigorous logical reasoning to find the answers. However, due to the lack of logical thinking ability of some high school students, they are often unable to effectively construct logical chains, resulting in problems such as

jumping in thinking and confusing reasoning in the process of solving problems. For example, when solving complex algebra problems, they may not be able to gradually deduce the unknown quantity according to the known conditions but try to find the answer through guessing or trial and error, and this kind of lack of logic in problem-solving is not only inefficient but also prone to errors.

4. Effective measures to overcome cognitive barriers in high school mathematics

4.1. Strengthen the teaching of basic knowledge

To overcome the conceptual understanding barrier of statistics, teaching should be carried out in the following aspects. Firstly, one should make sure that the student has mastered the basics of statistics, including the basic methods of data collection, organization, description, and analysis, and by systematically reviewing and consolidating these basics, the student can lay a solid foundation for the subsequent learning [8]. Second, for each statistical concept, one should carefully read the definitions and explanations in the textbook or reference books and understand them with practical examples. For example, the mean is used to measure the central tendency of a set of data. The formula is: mean = (sum of data)/(number of data). Variance is a measure of the dispersion of a set of data and is calculated as Variance = Σ[(xi-mean)^2]/(number of data), where xi is each data point. The median is the number that lies in the middle of a set of data when it is arranged in order of size. For an even number of data, the median is the average of the middle two numbers, and so on.

To better remember these concepts, the connection and difference between related concepts can be presented by drawing concept maps and making mind maps. At the same time, it is important to deepen the understanding of statistical concepts and the ability to apply them through a large number of exercises and case studies. One can choose some representative statistical problems and try to apply what they have learned to analyze and answer them, to consolidate and expand your knowledge system. In addition, if one encounters problems that are difficult to solve in the learning process, they can seek help from their teacher, classmates, or the online community. Meanwhile, by actively participating in classroom discussions and group activities, and sharing their learning tips and experiences with others, they can also get valuable feedback and suggestions.

Take a question for example: A high school has three grades: freshman, sophomore, and junior, with 300 students in the freshman year, 350 in the sophomore year, and 350 in the junior year. To find out how satisfied the students are with the school cafeteria, a questionnaire survey is planned to be conducted using a simple random sampling of 100 students from the entire school population. How will this be done?

Solution process and analysis:

Determine the sampling ratio: First, the sampling ratio needs to be calculated, which is the ratio of the number of students in the sample to the total number of students. The total number of students in the school is 300 (senior) + 350 (sophomore) + 350 (junior) = 1000. Therefore, the sampling ratio is 100/1000= 1/10.

Stratified Sampling: Since the number of students in senior one, senior two, and senior three are different, to ensure that students in each grade are represented accordingly in the sample, stratified sampling needs to be carried out first. Based on the number of students in each grade and the sampling ratio, the number of students that should be sampled from each grade can be calculated.

Number of students to be sampled in the first year of high school: 300 x 1/10 = 30 (persons)

Number of students to be sampled for sophomore year: 350 x 1/10 = 35 (persons)
Number of students to be drawn for senior year: 350 x 1/10 = 35 (persons)

4.2. Strengthening data processing and analysis

To address these barriers, firstly, an understanding of the basic concepts and methods of data processing should be strengthened. They need to master how to collect and organize data, including how to identify and correct errors and outliers in data. In addition, they need to understand the characteristics of different types of data (such as continuous variables, discrete variables, categorical variables, and so on) and how they are handled. Secondly, in terms of data analysis, students should learn and master commonly used statistical methods, such as descriptive statistics (mean, median, plurality, standard deviation, and so on), inferential statistics (hypothesis testing, and others), and correlation and regression analyses. They should understand the principles and application scenarios of these methods, and be able to select appropriate methods for analysis according to the nature of the problem and the characteristics of the data. In terms of specific mathematical calculation methods, students need to master the relevant formulas and calculation methods. For example, in descriptive statistics, they need to master how to calculate the mean, median, plural, and standard deviation. In addition to mastering basic statistical methods and calculations, students should also focus on practical applications. They can practice their data processing and analysis skills by participating in actual data analysis projects. In the projects, they can apply the statistical methods and computational methods they have learned to process and analyze actual data and try to interpret and reason about the results of the analysis.

4.3. Cultivating abstract and logical thinking skills

One of the effective measures to overcome the cognitive barriers in high school mathematics is to actively cultivate abstract thinking and logical thinking abilities. Taking mathematical calculation as an example, doing more logical reasoning problems is an effective way to improve the activity of thinking and cultivate abstract thinking ability. Mathematical calculation often involves a lot of logical reasoning, which requires students to have a high level of abstract thinking ability. By practicing a lot of logical reasoning problems, students can exercise their flexibility and depth of thinking, and gradually adapt to and understand the abstract concepts in mathematics. For example, when learning set operations, they can gradually deepen their understanding of the concept of sets and their rules of operations by solving logical reasoning problems containing different sets. Such exercises help to improve the level of abstract thinking and enable them to better understand and apply mathematical knowledge. Secondly, exercising logical thinking skills through problem-solving is also a key measure to overcome cognitive barriers in mathematics. Mathematical computing is essentially a problem-solving process that requires the use of logical thinking to analyze and solve problems. In practical learning, one should actively participate in the process of exploring and solving problems, and exercise one's logical thinking ability through steps such as analyzing the conditions of the problem, establishing mathematical models, and deriving conclusions. For example, when solving complex series problems, one needs to analyze the recurrence relationship or summation formula of the series and find the key steps to solve the problem through logical reasoning. Such exercises not only improve logical thinking skills but also enhance confidence and interest in solving mathematical problems.

4.4. Cooperation and support from schools and families

Overcoming cognitive disabilities in mathematics in senior secondary schools also requires close collaboration and support from schools and families. On the school side, teachers can cooperate and support students to overcome cognitive barriers in mathematics in the following ways. On the one hand, personalized teaching plans are key. Each student's mathematical foundation and learning ability are different, so teachers should make individualized teaching plans according to each student's specific situation [9]. For students who have difficulties in mathematical computation, teachers can provide additional teaching resources and tutorials to help them understand basic concepts and computational methods [10]. Alternatively, they can design targeted exercises to help students consolidate their knowledge and skills. On the other hand, it is also important to establish positive teacher-student interactions. Teachers should encourage students to actively speak, ask questions, and discuss in class. By interacting with students, they can understand students' confusion and difficulties in mathematical computation to provide more effective guidance and assistance.

On the home front, it is crucial to establish a favorable home learning atmosphere. Parents should create a quiet, tidy, and orderly learning environment for students so that they can concentrate on their studies. At the same time, parents can also encourage students to carry out mathematical computation exercises at home, such as completing homework and taking part in mathematical competitions, to enhance students' interest in mathematics and their computational ability. Secondly, it is also important to pay attention to children's learning progress and give encouragement. Parents should communicate with their children regularly to understand their learning situation and difficulties in mathematical computation and encourage them to face challenges positively and seek solutions. When children make progress in mathematical computation, parents should give them timely recognition and encouragement to boost their self-confidence and motivation in learning. In addition, home-school cooperation is also an important way to overcome cognitive impairment in mathematics. Parents can learn about the school's teaching plans and requirements through these channels, and actively cooperate with the school's educational work, to jointly help students overcome the cognitive impairment in mathematics.

5. Conclusion

In conclusion, the formation of high school mathematics cognitive impairment is not a one-time event, but the result of a variety of factors, therefore, it needs the joint efforts of schools, families, and themselves to start from various aspects and take comprehensive measures. Looking ahead, it is expected that the American education system will pay more attention to student's individual differences and cognitive characteristics, and develop more personalized teaching programs to help students overcome their cognitive disabilities in mathematics. At the same time, home-school cooperation and community participation will jointly promote the reform and development of American high school mathematics education. It is believed that, with the joint efforts of everyone, American high school mathematics education will be able to make more significant progress and achievements.

Disclosure statement

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