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Research on the Evaluation System of College Students' Numeracy: based on Analytic Hierarchy Process

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Abstract

As an important part of the core quality of social members, improving the mathematical literacy of college students has become a fundamental task of contemporary education. In recent years, Numeracy has received widespread attention from all walks of life. How to improve students' numeracy has become a hot topic in educational research. In this paper, the mathematical modeling, visual imagination, mathematical abstraction, logical reasoning, data analysis and mathematical operation are taken as the primary indexes of mathematical literacy to abstract sixteen secondary indexes of numeracy by combining the advice of the experts and using questionnaires. Then the quantitative weights of two evaluation indexes of numeracy are given through the analytic hierarchy process and comprehensive evaluation and other methods, and some secondary evaluation indexes having been improved. Thus, a set of evaluation index system of college students' numeracy has been constructed.

Keywords

College students; Numeracy; Index system; Analytic hierarchy process.

1. Research Background

The thoughts and methods of modern mathematics have been integrated into many subjects such as society, economy, biology, information and so on. In order to cultivate students with good numeracy, this is also the basic requirements for contemporary college students.

The word “Numeracy” was first known to the public in 1959 when it was first popularly known in the Matteson’s report of the United Kingdom[1]. After more than half a century of perfection and development, it has been agreed that "Numeracy" is based on the accumulation of common knowledge in mathematics itself, which can be explicitly reflected in the process of guiding mathematical activities in specific situations with holistic behavior characteristics and systematic scientific ideas[2]. According to "Mathematics Curriculum Standard of Full-time compulsory Education"[3] and "Mathematics Curriculum Standard of General Senior High School (Experimental draft)"[4], and combing and summing up the relevant literature, we find that the numeracy of college students should be embodied in six aspects: mathematical modeling, visual imagination, mathematical abstraction, logical reasoning, data analysis and mathematical operation. However, by combing and summarizing the relevant literature, it is found that most of the studies have defined the concept of Numeracy in six aspects from the qualitative point of view, and described its role, significance and cultivation in mathematics and life. But there is no secondary index of numeracy in six aspects, and there is a lack of the construction of Numeracy index system, and the quantitative study on it is carried out.

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2. Research Methods

This paper attempts to elaborate the construction of the evaluation index system of college students' numeracy from the following three aspects: Firstly, through the interpretation of six aspects of numeracy, put forward reasonable secondary indicators; Secondly, through the in-depth interviews with teachers and managers, the secondary evaluation index is summed up to form a preliminary evaluation index system of numeracy. Thirdly, through the questionnaire survey of experts, the weight coefficient between the indexes is calculated by using the analytic hierarchy process. Fourthly, the reliability and validity of the evaluation index system are tested.

Due to the limitation of time and space, the interview is mainly conducted in Hubei Polytechnic University and Hubei normal University, and the subjects of the interview are the teaching and management staff with middle and senior professional titles and doctorate degrees in these two colleges and universities.

2.1. Index System

Based on the principles of scientificalness, feasibility and completeness, the evaluation system of college students' mathematical literacy is set up through the reference of relevant literature and the arrangement and analysis of expert interview feedback. The specific steps are as follows:

2.2. Questionnaire Design

In the questionnaire, we ask experts to score the indexes according to the necessity of reflecting the numeracy of college students. The necessity given by us is divided into five grades, and the specific manifestations are: A score of 5 indicates that it is very necessary. A score of 4 indicates that it is necessary. A score of 3 indicates that it is general. A score of 2 indicates that it is unnecessary. A score of 1 is totally unnecessary. At the end of the evaluation, we also invited experts to propose their own amendments.

2.3. Measurement

In order to serve our screening and measurement of related indexes, we need to use the necessary means to measure the concentration trend of data based on the relevant knowledge and basic methods of statistics. The coefficient of variation is used to measure the discrete trend of the data. The mean value of necessity: This index reflects the concentration trend of data, which is the most common statistical measure in statistics. Its actual meaning is to look at the importance of a specific index in the whole selected index system from the point of view of average value. The larger the value is, the more important the corresponding index is, that is, the higher the average recognition of the index is. Coefficient of variation: it represents a ratio of the standard deviation of the obtained data to the average of the obtained data[5]. The value of the index is generally in the range of 0.05-0.35. If the value is less than 0.15, it means that the dispersion of the obtained data is low, which is acceptable. The smaller the value of the index, the higher the degree of coordination among the opinions given by the experts, and the more consistent the experts' attitude towards the importance of the evaluation index is.

3. Results

3.1. The Second-level Index Consultation Result Analysis

According to our choice of necessity mean and coefficient of variation, through the Table 1 shows, the necessity of problem solving, mathematical expression and innovation consciousness is a little high, and the variation coefficient is low, it shows that the three indicators should be mathematical abstraction of secondary indexes. But the necessity of the

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index of mathematics humanities mean obviously lower than other index, at the same level and the variation coefficient is 0.1622, higher than 0.15, suggesting that should not be set for mathematical modeling of mathematics humanities index at a lower level. Therefore, the problem solving, mathematical expression and innovation consciousness are the second-level index under the mathematical modeling.

Table 1. Second-level index consultation results under mathematical modeling

Second-level index	Necessity mean	Standard deviation	Coefficient of variation
Solution problem	4.92	0.39	0.0793
Mathematical expression	4.78	0.51	0.1067
Mathematical humanities	4.13	0.67	0.1622
Innovative consciousness	4.85	0.43	0.0887

Also, through the analysis of Table 2 shows that should not mathematics comprehension as intuitive imagination indicators at a lower level, therefore, intuitive, space concept, and we will figure combination as intuitive imagination sets of second-level index.

Table 2. Second-level index consultation results under intuitive imagination

Second-level index	Necessity mean	Standard deviation	Coefficient of variation
Intuitive figures	4.58	0.63	0.1376
Space concept	4.66	0.54	0.1159
Combination of number and shape	4.80	0.49	0.1021
Mathematics comprehension	4.45	0.87	0.1955

Table 3. Second-level index consultation results under mathematical abstractions

Second-level index	Necessity mean	Standard deviation	Coefficient of variation
Mathematical induction	3.40	0.55	0.1618
Mathematical knowledge	4.57	0.48	0.1050
Mathematical summary	4.83	0.35	0.0725
Symbol consciousness	4.84	0.26	0.0537

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Also, through the analysis of Table 3, the experts don't approve of setting mathematical induction as mathematical abstraction indicators at a lower level, therefore, we would use mathematical knowledge, mathematics generalization and symbolic consciousness as a mathematical abstraction sets of second-level index.

Similarly, it can be seen from Table 4 that judgment inference should not be set as a subordinate indicator of logical reasoning. Therefore, logical reasoning, deductive reasoning and inductive generalization are used as second-level index of logical reasoning.

Table 4. Second-level index consultation results under logical deduction

Second-level index	Necessity mean	Standard deviation	Coefficient of variation
Plausible reasoning	4.74	0.62	0.1308
Judgment reasoning	4.45	0.72	0.1618
Deductive reasoning	4.85	0.23	0.0474
Summarizing	4.65	0.59	0.1269

Similarly, it can be seen from Table 5 that experts are opposed to setting multi-dimensional thinking as a subordinate index for data analysis. Therefore, we will analyze data and application data as second-level index for data analysis.

Table 5. Second-level index consultation results under data analysis

Second-level index	Necessity mean	Standard deviation	Coefficient of variation
Analytical data	4.65	0.61	0.1312
Application data	4.95	0.67	0.1354
Multidimensional thinking	4.40	0.75	0.1705

Similarly, through the analysis of table 6, it is known that the numerical calculation should not be set as the subordinate index of mathematical operation, therefore, the number sense and algebraic operation are the secondary indexes of mathematical operation.

Table 6. Second-level index consultation results under mathematical operation

Second-level index	Necessity mean	Standard deviation	Coefficient of variation
Number sense	4.79	0.26	0.0543
Numeric Calculation	4.26	0.67	0.1573

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algebraic operation	4.86	0.43	0.0885

According to the above analysis, the mathematical literacy evaluation index system of college students is obtained, which consists of six primary indexes and 16 secondary indicators, as shown in Table 7.

Table 7. College students' mathematical literacy education evaluation index system

First-class index	Second-level index	First-class index	Second-level index
Mathematical modeling	Problem solution	Intuitive imagination	Intuitive figures
	Innovative consciousness		Space concept
	Mathematical expression		Combination of number and shape
Mathematical abstractions	Mathematical knowledge	Logical deduction	Plausible reasoning
	Mathematical		Deductive reasoning
	Symbol consciousness		Summarizing
Data analysis	Analytical data	Mathematical operation	Number sense
	Application data		Algebraic operation

3.2. Index Weight

3.2.1. Calculation of the Weight Coefficient of the First-level Evaluation Index

Analytic hierarchy process is a multi-criteria decision method pioneered by professor Saaty ,the university of Pittsburgh in the mid-1970s [6-9]. We use this to evaluate the mathematical accomplishment, and the detailed calculation steps are as follows [6] :

Based on the 1-9 scale determination method, the following first-level evaluation index judgment matrix is constructed, as shown in Table 8.

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Table 8. Judgment matrix of primary evaluation index

First-class indexes	Mathematical modeling	Intuitive imagination	Mathematical abstractions	Logical deduction	Data analysis	Mathematical operation
Mathematical modeling	1	1/4	1/5	1/3	1	1/3
Intuitive imagination	4	1	2	1	2	1
Mathematical abstractions	5	1/2	1	2	2	1
Logical deduction	3	1	1/2	1	1/2	1/3
Data analysis	1	1/2	1/2	2	1	1/2
Mathematical operation	3	1	1	3	2	1

The relative weights of the two comparisons can also be represented by the matrix.

$$A=\begin{bmatrix} 1 & \frac{1}{4} & \frac{1}{5} & \frac{1}{3} & 1 & \frac{1}{3} \\ 4 & 1 & 2 & 1 & 2 & 1 \\ 5 & \frac{1}{2} & 1 & 2 & 2 & 1 \\ 3 & 1 & \frac{1}{2} & 1 & \frac{1}{2} & \frac{1}{3} \\ 1 & \frac{1}{2} & \frac{1}{2} & 2 & 1 & \frac{1}{2} \\ 3 & 1 & 1 & 3 & 2 & 1 \end{bmatrix}$$

Based on the above comparison judgment matrix, the corresponding eigenvector and the maximum characteristic root are calculated.

$$\overline{w_i}=\left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}}=[0.421 \quad 1.587 \quad 1.468 \quad 0.794 \quad 0.794 \quad 1.619]^r$$

Again to $\overline{w_i}$ normalized processing:

$$w_i=\frac{\overline{w_i}}{\sum_{j=1}^{n}\overline{w_i}}=\left[\frac{0.421}{6.683} \quad \frac{1.587}{6.683} \quad \frac{1.468}{6.683} \quad \frac{0.794}{6.683} \quad \frac{0.794}{6.683} \quad \frac{1.619}{6.683}\right]^r$$

$$=[0.063 \quad 0.237 \quad 0.220 \quad 0.119 \quad 0.119 \quad 0.242]^r$$

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Thus, the following eigenvectors can be obtained:

$$W = [0.063 \quad 0.237 \quad 0.220 \quad 0.119 \quad 0.119 \quad 0.242]^r$$

The corresponding maximum characteristic root is.

$$\lambda_{max} = 6.397$$

Calculate the consistency index.

$$CI = \frac{\lambda_{max} - 1}{n - 1} = \frac{6.397 - 6}{6 - 1} - 0.079$$

Take RI =1.26 according to the random consistency index. The consistency ratio can be calculated as follows:

$$CR = \frac{CI}{RI} = \frac{0.079}{1.26} = 0.063$$

Since the consistency ratio is less than 0.1, the weight coefficient can be used for decision analysis. Therefore, the weight coefficient of the expert evaluation index is shown in Table 9.

Table 9. The weight coefficient of first-class indexes

First-class indexes	Weight coefficient	First-class indexes	Weight coefficient
Mathematical modeling	0.063	Intuitive imagination	0.237
Mathematical abstractions	0.220	Logical deduction	0.119
Data analysis	0.119	Mathematical operation	0.242

3.2.2. The Calculation of the Weight Coefficient of the Secondary Index

For the calculation of the weight coefficient of the secondary index, the method of hierarchical analysis is still adopted, so only two are listed. The weight coefficients of the grade indicators are shown in table 10-15.

Table 10. The second-class indexes weight coefficient under mathematical modeling

Mathematical modeling	Solution problem	Innovative consciousness	Mathematical expression	Weight coefficient
Solution problem	1	2	2	0.500
Innovative consciousness	1/2	1	1	0.250
Mathematical expression	1/2	1	1	0.250
CI =0 RI =0.52 CR =0				

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Table 11. The second-class indexes weight coefficient under intuitive imagination

	Combination of number and shape	Space concept	Intuitive figures	Weight coefficient
Combination of number and shape	1	1/4	1	0.167
Space concept	4	1	4	0.666
Intuitive figures	1	1/4	1	0.167
CI =0 RI =0.52 CR =0				

Table 12. The second-class indexes weight coefficient under mathematical abstractions

Mathematical abstractions	Symbol consciousness	Mathematical summary	Mathematical knowledge	Weight coefficient
Symbol consciousness	1	1/3	2	0.238
Mathematical summary	3	1	4	0.625
Mathematical knowledge	1/2	1/4	1	0.137
CI =0.0093 RI =0.52 CR =0.0179				

Table 13. The second-class indexes weight coefficient under logical deduction

Logical deduction	Summarizing	Deductive reasoning	Plausible reasoning	Weight coefficient
Summarizing	1	2	2	0.558
Deductive reasoning	1/2	1	1/3	0.122
Plausible reasoning	1/2	3	1	0.320
CI =0.0092 RI =0.52 CR =0.0177				

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Table 14. The second-class indexes weight coefficient under data analysis

Data analysis	Application data	Analytical data	Weight coefficient
Application data	1	1	0.500
Analytical data	1	1	0.500
CI =0 RI =0 CR =0			

Table 15. The second-class indexes weight coefficient under mathematical operation

Mathematical operation	Number sense	Algebraic operation	Weight coefficient
Number sense	1	2	0.667
Algebraic operation	1/2	1	0.333
CI =0 RI =0 CR =0			

3.2.3. The Calculation of the Combined Weight Coefficient

By using the principle of probability multiplication, the weight coefficient of indexes at all levels is in the order of the subordinate to the superior. In order to multiply, the weight coefficient can be combined. The specific weight coefficients are shown in Table 16.

4. Evaluation Index System Verification

4.1. Reliability Analysis

This passage adopted Cronbach reliability coefficient.

$$\alpha = \frac{n}{n-1}\left(1 - \frac{\sum_{i=1}^{n} S_i^2}{S_x^2}\right)$$

Among them, n represents the number of questionnaire design subjects, S_i^2 represents scores of variance on a certain topic, S_x^2 represents total variance in scores on the questionnaire. Using SPSS to calculate the reliability is 0.912, indicating that the reliability of the research findings is desirable. Therefore, the evaluation index system of college students' mathematics accomplishment is reliable.

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Table 16. The weight coefficient of mathematical literacy evaluation index system of college students

Decision objective	First-class indexes	Second-level index	Synthetic weight
Evaluation index system of mathematics literacy of college students. (1.000)	B1Mathematical modeling (0.063)	C1 Problem solution(0.500)	0.0330
		C2 Innovative consciousness(0.250)	0.0150
		C3 Mathematical expression(0.250)	0.0150
	B2 Intuitive imagination(0.237)	C4 Combination of number and shape(0.167)	0.0400
		C5 Space concept(0.666)	0.1570
		C6 Intuitive figures(0.167)	0.0400
	B3 Mathematical abstractions (0.220)	C7 Symbol consciousness(0.238)	0.0520
		C8 Mathematical summary(0.625)	0.1380
		C9 Mathematical knowledge(0.137)	0.0300
	B4 Logical deduction (0.119)	C10 Summarizing(0.558)	0.0660
		C11 Deductive reasoning (0.122)	0.0140
		C12 Plausible reasoning(0.320)	0.0390
	B5 Data analysis (0.119)	C13 Application data(0.500)	0.0595
		C14 Analytical data(0.500)	0.0595
	B6 Mathematical operation (0.242)	C15 Number sense(0.667)	0.1610
		C16 Algebraic operation(0.333)	0.0810

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4.2. Validity Analysis

Validity usually consists of two aspects: surface validity and content validity, which reflects the degree of objective authenticity of objects.

Surface validity refers to the research results obtained in accordance with the general opinions and understandings of the experts or the public on the issue or things. Single and combined the related analysis, this article USES calculated by SPSS software, and the scores of each item total correlation coefficient r=874.0, so under the 95% significant level, determine the research results of face validity is good.

Content validity refers to the degree of approval of the experts to the target object of the research, measurement or evaluation. This article mainly uses the factor analytic method to analysis the content validity of the questionnaire, through the SPSS software options, analysis, dimension reduction, factor analysis, all the subjective topic choice: "project", click on the description, choose KMO test, click to rotate, choose the maximum variance method, click options, and sorted by size. Get KMO = 0.893.Therefore, the evaluation index system constructed in this study has good content validity.

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