Mathematics Learning Strategy Scales for Junior High School Students: Scale Development, Validation and Intelligent Application

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Abstract: *Mathematics learning strategies are an important part of the psychological structure of high-quality mathematics students. How to measure and evaluate students' mathematics learning strategies Level is of great significance in related quantitative research. Based on the existing research on mathematics learning strategies, a set of mathematics learning strategy scales suitable for Chinese junior high school students and with mathematics learning characteristics were compiled. This research has done 4 times of data collection (a total of 959 valid questionnaires), item analysis, confirmatory factor analysis and exploratory factor analysis, which proved the validity of the scale in the measurement of mathematics learning strategies. In this study, the mathematics learning strategies of junior high school students were divided into 3 main aspects: Mathematics Cognitive Strategies, Mathematics Meta-cognitive Strategies, Mathematics Resource Management Strategies; 10 kinds of sub-dimensions: Retelling, Elaboration, Organize, Planning, Monitoring, Feedback-Adjustment, Time-management, Environment-management, Mood-management, Help-seeking. According to the operational definition, test results show that the questionnaire has good reliability and validity, which can be used as an effective measurement tool for mathematics learning strategies of junior high school students. The study has written the scale into an intelligent batch assessment system of mathematics learning quality for primary and secondary school students, providing an accurate and convenient test of mathematics learning strategies for a wide range of junior secondary school students in an automated and intelligent manner, and providing accurate measurement reports and personalized improvement strategies for each student tested.*

1. Introduction

Forty years ago, teachers and scholars have realized that traditional classroom teaching methods are often not the best way for students to acquire knowledge and apply it in practice(see[1]), instead, enabling students to have the ability to learn and master learning strategies has become an important factor affecting their learning achievements(see[2]).Under the circumstance of the new era, UNESCO regards "learn to learn" as the core of education in the 21st century, and "learn to learn" is more important than "learn knowledge". Once learners have the ability to learn, they will be able to learn new knowledge, new technology, accept new challenges and undertake new tasks. Mastering learning strategies is the basis for measuring how to learn, and a good learning strategy is a powerful tool to help students make mathematics achievements (see [3], [4], and [5]). Mathematics learning strategies have always been playing an important role in mathematics learning. Measuring and evaluating the level of students' mathematics learning strategies have also become an important link in related quantitative research.

Judging from existing researches, many measurement tools such as *Motivated Strategies for Learning Questionnaire* (MSLQ) (see[6]), *Learning and Study Strategies Inventory* (LASSI-HS) (see[7]) and *High School Students Mathematical Learning Strategy Questionnaire* (see[8]) have been compiled by domestic and foreign scholars. However, these researches are not enough to reflect the mathematics learning characteristics of junior high school students in the compulsory education of our country, and because some scales have been formulated for a long time, and many studies have not been revised but used directly, making it difficult to ensure its the effectiveness.

In March 2021, China's Ministry of Education and other six departments jointly issued the *Guidelines for Compulsory Education Quality Evaluation*, which pointed out clear instructions and requirements in terms of student development, academic development, and physical and mental development. As a non-intellectual factor, learning strategy has a great influence on the learning process and academic performance of junior high school students. Therefore, based on the purpose of better understanding and measuring the learning strategies of junior middle school students in compulsory education at this stage, this study compiled a set of reliable and valid mathematics learning strategy scale considering the mathematics learning process of junior secondary school students in China. According to the learning characteristics of junior high school students and the actual use of learning strategies, this scale provided targeted theoretical references and evaluation tools for the teaching of junior high school mathematics strategies.

2. Multifaceted definition of learning strategies

2.1. Definition and classification of learning strategies

As an important research direction in psychology and pedagogy, a lot of definitions towards learning strategies have been carried out by scholars. Rigney (see[9]) proposed that learning strategies are various operations and procedures that students use to acquire, maintain and extract knowledge and homework. Bråten and Strømsø (see [10]) pointed out that students who were good at using organizational strategies were better at obtaining good performance. According to Winstein (see [7]), in a broad sense, learning strategies refer to various abilities that are helpful and necessary for effective learning and maintaining information, as assumed by researchers and practitioners. Haga (see [11]) pointed out that learning strategies are strategies affecting learners' self-information processing activities. All activities that can promote learning are learning strategies, such as memory methods, constructing connections between knowledge, taking notes, making comments, drawing marks, etc. According to the definition by Chamot (see [12]), learning strategies are skills, methods, or actions that can be directly carried out, which helps improve the learning effect, optimize the learning process, and strengthen the memory of language knowledge. Generally speaking, learning strategies refer to procedures, rules, methods, techniques, and control methods that learners effectively learn in learning activities, it can be either an implicit rule system or explicit operating procedures and steps.

There are different opinions on the definition of the concept of learning strategy in the academic circle, and they also have different views on the structure of learning strategies. Representative classifications are as follows. Rigney (see [9]) believed that learning strategies consisted of independent and inclusive strategies. Weinstein and Goetz (see [13]) believed that learning strategies included cognitive information processing strategies, such as finishing strategies, and active learning strategies, such as test-taking strategies. Supplementary strategies, such as strategies for dealing with anxiety; meta-cognitive strategies, like those for monitoring the acquisition of new information. Pintrich (see [14] and [15]) believed that the most basic cognitive strategy was rehearsal, more complex strategies were elaboration and organization; based on learning strategies, Dansereau (see [16]) divided learning strategies into two types: basic strategies and supporting strategies. Basic strategies refer to various learning strategies in which materials can be directly manipulated, which mainly includes information acquisition and storage, information retrieval and application, such as memorization, organization and recalling strategies. Supporting strategies mainly refer to strategies that help learners maintain an appropriate learning mentality, so as to ensure the effective operation of basic strategies, such as focused attention strategies, self-monitoring and judgement strategies. Mckeachie etc. (see [6]) sorted out them as cognition based on the components covered by the learning strategy, meta-cognitive strategy, resource management strategy. Cognitive strategies include retelling strategies, finishing strategies, and organizational strategies; meta-cognitive strategies include planning strategies, monitoring strategies, and adjustment strategies; resource management strategies include time management strategies, learning environment management strategies, effort management, and support from others and so on.

2.2. Tools for measuring learning strategies

In the establishing process of many learning strategy measurement tools, there is a certain similarity in the structure of learning strategies by foreign researchers. Among them, the most representative and most widely used is the MSLQ scale established by Pintrich, Mckeachie and so on (e.g. [6]and [17]). In terms of the classification of learning strategies, it consists of three categories: mathematical cognitive strategies, mathematical meta-cognitive strategies, and mathematical resource management strategies, in these strategies, 81 items and 15 sub-dimensions were included to evaluate students' learning motivation and learning strategies. Berger (see[18]) established a targeted scale for middle school students' cognitive strategies according to Mckeachie's research. Liu (see [19]) established a learning strategy scale for middle school students based on the research of Mckeachie et al. Secondly, The Learning and Study Strategies Inventory established by Weinstein (see [20]) divides learning strategies into 10 sub-dimensions, namely: attitude, motivation, time organization, anxiety, concentration, information processing, selection of main ideas, use of techniques and support materials, self -assessment, testing strategies.

Chinese researchers have compiled a series of questionnaires on mathematics learning strategies. For example, Liu’s (see [21]) *Mathematics Learning Strategy Scale for Primary School Students* contains two main dimensions: mathematics meta-cognitive strategies (including planning strategies, monitoring and adjustment strategies, evaluation of reflection strategies, strategic awareness) and mathematical cognitive strategies (including mathematics concept strategies, computational learning strategies, application problem solving strategies, geometric knowledge learning strategies).*The Middle School Students' Mathematics Learning Strategy Scale* compiled by Yao (see[22]) contains four dimensions: mathematics meta-cognitive strategy, cognitive strategy, resource management strategy and emotional strategy. The Questionnaire on Mathematics Learning Strategies for High School Students compiled by Wang Guangming divides mathematics learning strategies into mathematics cognitive strategies, mathematics meta-cognitive strategies and mathematics resource management strategies.

3. Methods

3.1. Model construction

Integrating literature data and existing mature scales, combining expert opinions, dimensions and model of the questionnaire are finally determined (Fig. 3.1.1), which contains 3 primary dimensions and 10 secondary dimensions. The operational definitions of each dimension are shown in Table 3.1.1.

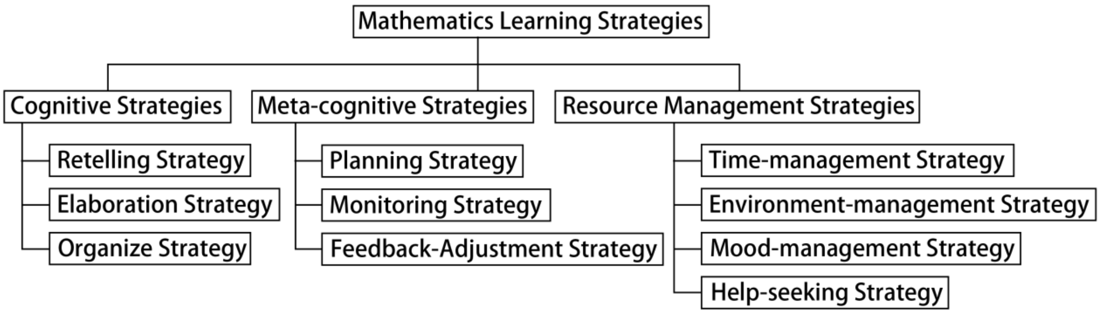

Fig. 3.1.1 Dimension division of mathematics learning strategies

Table 3.1.1 Operational definition of sub-dimension of mathematics learning strategy

First-level dimension	Second-level dimension	Definition of operation concept
Mathematics Cognitive Strategies	Retelling Strategy	It refers to the strategy of reproducing learning materials or stimuli in order to remember and retain relevant concepts, propositions, properties, inferences, solutions, etc. in mathematics, by means of timely review, repeated practice, multiple representation and elimination of interference in order to form long-term memory.
	Elaboration Strategy	It refers to the strategy of self-coding, translating, explaining and distinguishing different mathematical objects and situations, choosing appropriate ways, such as adding details, giving examples and forming associations, to express mathematical content and construct meaningful learning.
	Organize Strategy	It refers to the integration of mathematical knowledge with a holistic view, sorting and summarizing according to the characteristics or categories of mathematical knowledge, forming a clear knowledge network structure, from which a mathematical method or mathematical model can be selected or designed to

		solve problems through thinking and judgment.
Mathematics Meta-cognitive Strategies	Planning Strategy	It refers to the overall planning of mathematics learning, as well as the strategy of reasonable planning and arrangement of specific learning content, time allocation, difficulty progress, methods and so on.
	Monitoring Strategy	It means that learners are alert to their own mathematical knowledge level, learning state, learning ability, learning effect, etc., and can find out abnormal situations in time, such as realizing that their poor ability of examining problems affects the correct rate of solving problems, realizing that they do not understand the concept of equation clearly, etc.
	Feedback -Adjustment Strategy	It refers to the summary and generalization of learners' success and failure experience in the process of mathematics learning; And when the mathematics learning state and the mathematics learning environment change, in order to maintain the good mathematics learning effect, the learners make changes in behavior, psychology and learning methods.
Mathematics Resource Management Strategies	Time-management Strategy	It refers to the strategy of improving the efficiency of mathematics learning, arranging learning time as a whole, making efficient use of the best time and making flexible use of fragmented time.
	Environment -management Strategy	It refers to the management methods and measures for the preservation of mathematical materials, the placement of mathematical tools and articles, and the creation of mathematical learning atmosphere for the convenience of mathematics learning, such as ensuring the quiet and undisturbed learning environment.
	Mood-management Strategy	It refers to self-motivation, motivation and confidence.
	Help-seeking Strategy	It refers to the strategy of seeking external tools such as concept map software, mind map software, graphic calculator and online resources to assist mathematics learning, or seeking human resources such as teachers and students to assist learning.

Scale pre-establishment

Questions of the initial questionnaire are mainly from:

Learning and Study Strategies Inventory (LASSI-HS) (see[7])

Questionnaire on Mathematics Learning Strategies for High School Students (see[8])

Mathematics Learning Strategies Scale (see[23])

Considering characteristics of Chinese junior high school students' mathematics learning, quoting and adapting the content of the above questionnaires, a 87-question questionnaire was established, including 26 cognitive strategies, 28 meta-cognitive strategies, 27 resource management strategies, and 6 polygraph questions. In the questionnaire, the LIKERT five-point method for scoring is adopted, and the question options "very consistent", "Consistent", "uncertain", "non-consistent", and "very non-consistent" are respectively scored as "5", "4", "3", "2", "1". Random method is adopted to arrange the order of questions.

3.2. Sample and procedure

In the preparation of the questionnaire, a total of 4 tests were carried out using the cluster sampling method. For questionnaires collected in each test, invalid questionnaires are eliminated through the following two steps. Step 1: Visual inspection, eliminate invalid questionnaires with regular, periodic, and uniform answers; Step 2: Continue to screen the rest questionnaires based on the polygraph questions. Remove questionnaire in which there are great differences in answers to polygraph questions.

Sample 1: Pre-test sample. Including students in 8 classes in 4 typical schools in Tianjin, namely, there are students of the seventh and eighth grade of Experimental Middle School, Fangzhou Experimental Middle School, Haihe Middle School, and Tianjin No. 5 Middle School, respectively. A total of 330 questionnaires were issued and 286 were collected. After a two-step questionnaire screening, 209 valid questionnaires were finally obtained.

Sample 2: Used for exploratory factor analysis in the process of scale formulation. Subjects of the survey came from 5 middle schools in Tianjin, Hubei, Liaoning, Gansu, and Jiangsu. A total of 610 questionnaires were issued and 552 questionnaires were collected. After a two-step questionnaire screening, 428 valid questionnaires were finally obtained.

Sample 3: Used for verification factor analysis in the scale formulation process. Participants came from three schools in Tianjin, Shandong and Guangzhou. A total of 300 questionnaires were issued and 264 questionnaires were collected. After a two-step questionnaire screening, 209 valid questionnaires were finally obtained.

Sample 4: Used to calculate the retest reliability of the scale. Students are selected from those who have participated in the second test in two middle schools. A total of 160 questionnaires were issued and 142 questionnaires were collected. After a two-step questionnaire screening, 113 valid questionnaires were finally obtained.

4. Results

4.1. Data analytic of scale

The 81 questions of the questionnaire (not including polygraph questions) were analyzed through the SPSS software: First, analyze the correlation between the scores of each question in sample 1 and the total scores of students' mathematics learning strategies using the total question correlation method, then delete the questions with Pearson difference correlation coefficient of less than 0.4… which are the question 2,7,21,34,40,47,58,61,73,74,77,78 and 80, and a total of 13 questions have been deleted. Secondly, after deleting the above 13 questions, the critical ratio method is adopted to test the significant difference in the mathematics learning strategy scores of the high score group (the last 27%) and the low score group (the first 27%) of sample 1, items with insignificant differences between high and low groups are excluded. It was found that after these items were deleted using the total correlation of items, there were significant differences between the high score and low score groups in the remaining items. After project analysis, 68 questions were left (not including polygraph questions).

After going through the item analysis to screen the questions, the exploratory factor analysis method was adopted in SPSS to analyze the data, modify and improve questions in the questionnaire. First, perform the Bartlett sphere test on the three main dimensions of the questionnaire, and the results are shown in Table 4.1.1. From the data in the table, we can see that the KMO values of the overall mathematics learning strategy and the three main dimensions are more than 0.89, and the Bartlett sphere test value is significant ($p<0.01$), indicating that it is suitable for factor analysis of sample data.

Table 4.1.1 Factor analysis test value of the initial data of the scale

	Mathematics Learning Strategies (Total)	Mathematics Cognitive Strategies	Mathematics Meta-cognitive Strategies	Mathematics Resource Management Strategies
KMO	0.891	0.921	0.910	0.918
χ^2	11023.317	2084.042	2180.029	1493.373
Sig.	0.000	0.000	0.000	0.000

Principal component analysis and maximum variance rotation method are adopted in SPSS software to determine the number of questionnaire factors and questions. The following principles are adhered to in terms of keeping questions in the questionnaire.

(1) The characteristic value of the factor is greater than 1;
(2) The factor loading value is at least higher than 0.4;
(3) The load on different factors is no more than 0.4;
(4) The extracted principal components are consistent with the steep-order test;
(5) Each factor contains at least 3 questions;
(6) Only delete one question at a time, and re-examine and analyze the new data after each question is deleted.

Principles of naming after factors are as follows:

(1) If the topic of a certain factor mainly comes from a certain sub-dimension of the mathematical learning strategy model, it is named after this sub-dimension;

(2) If the topics that contribute more than half of the variance of a certain factor are scattered from different sub-dimensions of the mathematical learning strategy model, then they should be named after by referring to the common mathematical learning strategies of these topics.

To identify the number of factors in the questionnaire and the number of questions for each factor, the principal component analysis method and the maximum variance rotation method were selected in SPSS. After exploratory factor analysis (refer to Table 4.1.2), the factor structure of the three main dimensions of the mathematical learning strategy is established, and its load value, common factor variance and factor contribution rate are obtained, and the four principal components of the mathematical cognitive strategy are extracted, the three principal components of cognitive strategy and the three principal components of mathematical resource management strategy.

Table 4.1.2 Rotated factor matrix for Mathematics Cognitive Strategies based on exploratory factor analyses constrained to three factors

Item	Factor loadings			Common factor variance
	1	2	3	
Q75	0.780			0.666
Q30	0.740			0.591
Q67	0.705			0.625
Q51	0.680			0.650
Q83	0.664			0.568
Q53	0.594			0.561
Q8		0.827		0.718
Q28		0.689		0.565
Q50		0.663		0.540
Q81		0.595		0.529
Q3			0.756	0.601
Q43			0.559	0.483
Q24			0.565	0.595
Q27			0.502	0.463
Cumulative percentage of variance (%)	24.182	44.269	58.252	

As is vividly shown in Table 4.1.2, in the factor structure matrix of the mathematical cognition strategy, the load value of each item after rotation is greater than 0.5, indicating that there is a close relationship between the item and the factor to which it belongs; In the common factor variance, the explanation of each question to the questionnaire is 0.4-0.8, indicating that the extracted factors can reflect the information of the original variables. The cumulative contribution rate of the three factors is 58.252%, indicating that this is a first-order three-factor structure, where factor 1 is an organization strategy, with a total of 6 questions; factor 2 is a finishing strategy, with a total of 4 questions; factor 3 is a retelling strategy, a total of 4 questions.

Table 4.1.3 Rotated factor matrix for Mathematics Meta-cognitive Strategies based on exploratory factor analyses constrained to three factors

Item	Factor loadings			Common factor variance
	1	2	3	
Q78	0.747			0.649
Q52	0.714			0.549
Q62	0.706			0.599
Q39	0.698			0.606
Q64	0.696			0.601

Q13	0.628			0.559
Q9	0.614			0.491
Q32	0.505			0.541
Q59		0.834		0.742
Q4		0.773		0.625
Q31		0.447		0.412
Q38			0.829	0.746
Q57			0.812	0.770
Q29			0.706	0.563
Cumulative percentage of variance (%)	28.990	45.846	60.689	

As is vividly shown in Table 4.1.3, in the factor structure matrix of the mathematical meta-cognition strategy, the load value of each item is above 0.5, which indicates there is a close relationship between the item and the factor to which it belongs. In the common factor variance, the explanation of each question to the questionnaire is 0.5-0.8, indicating that the extracted factors can reflect the information of the original variables. The cumulative contribution rate of the three factors is 60.689%, indicating that this is a first-order three-factor structure, where factor 1 is a reflective adjustment strategy with a total of 8 questions; factor 2 is a monitoring strategy with a total of 3 questions; factor 3 is a planning strategy, a total of 3 questions.

Table 4.1.4 Rotated factor matrix for Mathematics Resource Management Strategies based on exploratory factor analyses constrained to three factors

Item	Factor loadings			Common factor variance
	1	2	3	
Q44	0.852			0.748
Q42	0.677			0.525
Q33	0.595			0.457
Q22		0.836		0.719
Q72		0.800		0.715
Q84		0.510		0.454
Q56			0.721	0.579
Q5			0.692	0.506
Q37			0.636	0.518
Cumulative percentage of variance (%)	20.533	40.647	58.017	

As is vividly shown in table 4.1.4, in the factor structure matrix of the mathematical resource management strategy, the load value of each item is above 0.5, which indicates that these items are closely related to factors to which they belong; in terms of common factor variance, each item's explanation of the questionnaire are 0.4-0.8, which shows that the extracted factors can reflect the information of the original variables. The cumulative contribution rate of the three factors is 58.017%, indicating that this is a first-order three-factor structure, where factor 1 is a mood management strategy with a total of 3 questions; factor 2 is an environmental management strategy with a total of 3 questions; factor 3 is the outside world, a total of 3 questions for the help-seeking strategy.

Through item analysis and exploratory factor analysis, a total of 31 questions from the questionnaire were deleted, and 37 questions from the questionnaire on mathematics learning strategies (first edition) were retained. After deleting questions using the software's arithmetic values, it turned out that the division of dimensions and some questions were not ideal. The numerical value calculated by the software could be used as the basis for deleting the question, but the question couldn't be deleted blindly based on the numerical value. It is also necessary to consider whether the semantics of the reserved question are clear and concise, and whether it covers all dimensions. Considering the above reasons, the original dimensions need to be merged or split and renamed. To make questions in the questionnaire more consistent with characteristics of junior high school students' mathematics learning, and compile a questionnaire with good reliability and validity, students' responses to some questions in the mathematics learning strategy questionnaire (first edition) in the process of answering questions, the expression of some questions in the questionnaire is improved and modified. Subsequently, topics are mixed and sorted out, and the junior high school students' mathematics learning strategy level survey questionnaire (second edition) is finally determined, in which there is a total of 46 questions, including 42 formal questions and 4 polygraph questions (reliability questionnaire), the specific distribution of the questions is shown in Table 4.1.5.

Table 4.1.5 Item Distribution of Mathematics Learning Strategy Scale for Junior High School Students (2nd Edition)

Second-level dimension	NO.	Number of item
Retelling Strategy	3,17,24,27,41	5
Elaboration Strategy	2,8,28,46	4
Organize Strategy	1,6,7,15,30	5
Planning Strategy	12,26*,29,36,38,39	6
Monitoring Strategy	4,13,18,31,34,45	6
Feedback-Adjustment Strategy	9,10*,23,32	4
Time-management Strategy	19,25,44	3
Environment-management Strategy	11,16,21	3
Mood-management Strategy	33,40,42	3
Help-seeking Strategy	5*,20,37	3
Polygraph Test	11,14,35,43	4
Total		46

*Remarks: * are items with reversed scoring method*

Investigate sample two using using Mathematics Learning Strategy Scale for Junior High School Students (2nd Edition). First, process the collected data in advance, and then analyze the questionnaire data using use SPSS software based on the data processing method and analysis process in the initial research. The 15th and 17th questions are deleted, and 44 questions were left.Last but not least, the data is analyzed by exploratory factors, and the Mathematics Learning

Strategy Scale for Junior High School Students (3rd Edition) is determined. The specific distribution of questions is shown in Table 4.1.6.

Table 4.1.6 Item Distribution of Mathematics Learning Strategy Scale for Junior High School Students (3rd Edition)

First-level dimension	Second-level dimension	NO.	Number of item
Mathematics Cognitive Strategies	Retelling Strategy	3,24,27,41	4
	Elaboration Strategy	2,8,17,28	4
	Organize Strategy	1,6,7,30	4
Mathematics Meta-cognitive Strategies	Planning Strategy	12,26,29,36,38,39	6
	Monitoring Strategy	4,13,15,18,31,34	6
	Feedback-Adjustment Strategy	9,10,23,32	4
Mathematics Resource Management Strategies	Time-management Strategy	19,25,44	3
	Environment-management Strategy	11,16,21	3
	Mood-management Strategy	33,40,42	3
	Help-seeking Strategy	5,20,37	3
	Polygraph Test	11,14,35,43	4
	Total		44

Investigate the selected sample three through Mathematics Learning Strategy Scale for Junior High School Students (3rd Edition), then perform confirmatory factor analysis on the data collected from the questionnaire using AMOS software. The purpose of the verification factor analysis is to test whether there is a good fitting effect in the measurement results of the questionnaire and the conceptual model. The measurement model in the structural equation model is mainly used to test whether the various questions of the questionnaire can well constitute the 3 main dimensions (second-order factors) and 10 sub-dimensions (first-order factors) in the questionnaire. Before constructing the model, the first-order factors are tested. Then analyze the operation results of the AMOS software, first consider the load value of each topic in the dimension to which it belongs. According to the results, there are 25 questions with a load value of 0.6-0.8, 9 questions with a load value of 0.5-0.6, and 6 questions with a load value below 0.5. Questions with factor loading values less than 0.5 (questions 4, 5, 10, 12, 31, 34) are deleted, and 34 questions were left. Subsequently, observe the MI value of Covariances in Modification Induces. If the MI value is greater than 3.84, it is considered to be large enough. Under the premise that the causality of its parameters is supported by theory, it can be released, namely, deleted, so as to be estimated again. Observe the MI value of Covariances in the Modification Induces report of the result. If it is found that the correction index between 2 pairs of questions in the MI value is above 20, it indicates that there is a certain causal relationship between these questions.

Through the observation of the content of these questions, it is believed that there are indeed repetitive expressions in questions 6 and 7, questions 32 and 33 respectively. For example, question 6 "To consolidate the knowledge of mathematics I have learned, I will make a knowledge network by sorting out relevant knowledge" and question 7 "I will sort out and summarize the common test questions of mathematics in junior high school", there is a certain degree of homogeneity of expression, and one question can be deleted among them.The factor load of question 6 is less than that of question 7, therefore, delete question 6; the factor load value of question 32 is 0.71, while that of question 33 is 0.53. Therefore, delete question 33 because of its small factor load. Referring to the MI value in Regression Weights and combining the meaning of the sentence, question 29 was classified as a mood management strategy. According to the revised MI value, 2 questions were deleted, leaving a total of 32 questions.

Combining the theoretical framework model, a second-order verification factor analysis was performed on the model. The results of various indicators are shown in Table 4.1.7

Table 4.1.7 Fitting index of Second-order 3-factor model

Model	χ^2/df	RMSEA	NFI	TLI	CFI	GFI
Second order factor	1.452	0.048	0.866	0.901	0.905	0.802

As is vividly shown in the data in Table 8, the second-order 3-factor model has a better fitting effect. The standardized load value of the first-order factor of 32 questions is between 0.50-0.78, and that on the second-order factor is between 0.50 and 0.78. The standardized load value of first order on the second order is between 0.45-0.68, therefore, we believe that the fitting between the first-order 10-factor and second-order 3-factor model has a good fitting effect and is acceptable. After conducting verification factor analysis, it turns out that the structural validity is good, and the path analysis is carried out to construct the structural model. The structure model of the questionnaire and the correlation coefficient between the standardized load value and the second-order factor are shown in Figure 4.1.1.

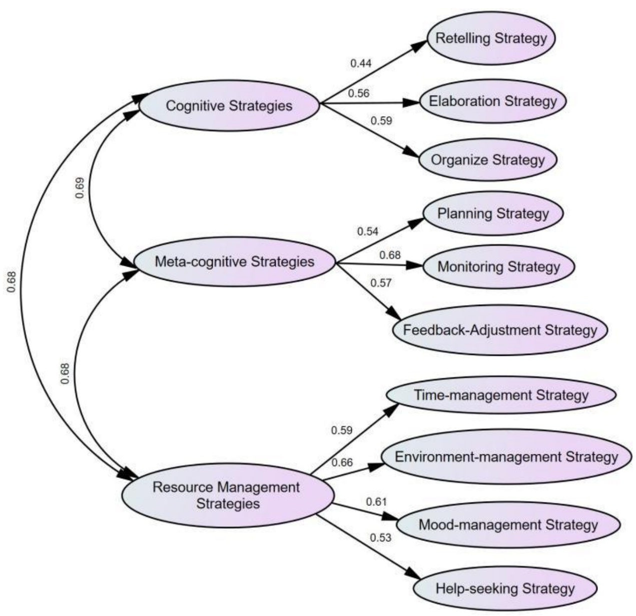

Fig. 4.1.1 Dimension model of mathematics learning strategies scale for junior high school

4.2. Reliability & validity of the scale

Reliability refers to the consistency, stability and reliability of the test results. The higher the reliability coefficient, the more consistent, stable and reliable the test results. This paper analyzes the reliability of the questionnaire by calculating the internal consistency and test-retest reliability. According to the results (Table 4.2.1), the Cronbach's α coefficients of main dimensions of the questionnaire on the level of mathematics learning strategies for junior high school students are between 0.83 and 0.89, and the Spearman-Brown split-half reliability is between 0.76 and 0.86, indicating that there is a high degree of consistency in the internal questions of main dimensions of the compiled strategy questionnaire. The Cronbach α coefficient of all questions in the questionnaire is 0.970, and the Spearman-Brown split-half reliability is 0.937, indicating that there is a good internal consistency in the compiled mathematics learning strategy questionnaire. In the retest, sample four is selected, and the Pearson product difference correlation method was adopted to calculate the retest reliability of the questionnaire, subsequently, the correlation between the two test scores is analyzed, according to the results, the retest reliability of each main dimension of the questionnaire is between 0.86-0.90, and the retest reliability of the total questionnaire is 0.906, from which we can see that there is a good internal consistency in the questionnaire. Combined with various reliability indicators, it is believed that the *Mathematics Learning Strategies Scale for Junior High School Students* is highly reliable.

Table 4.2.1 Reliability of Mathematics Learning strategies scale

Scale index	Cronbach's α coefficient	Spearman-Brown Split-half reliability	Retest reliability
Mathematics Cognitive Strategies	0.888	0.818	0.891
Mathematics Meta-cognitive Strategies	0.878	0.856	0.858
Mathematics Resource Management Strategies	0.839	0.768	0.792
Mathematics Learning Strategies	0.970	0.937	0.906

Content validity refers to the extent to which questions of the questionnaire can reflect the content being measured, and whether the purpose of the measurement can be achieved. Before the initial test questionnaire was formed, the content of the questions was borrowed from domestic and foreign scales or questionnaire, and the actual situation of mathematics learning of junior high school students in our country was taken into consideration; after that, I discussed with many experts, including the preparation of the questionnaire's guideline and questionnaire. The structure of the questionnaire and precautions for the preparation of the question, etc., are revised or deleted according to opinions of experts, and the survey model is constructed to determine questions of the *Questionnaire on The Level of Mathematics Learning Strategies for Junior High School Students.* In terms of the evaluation of the content validity of the final version of the questionnaire, four experts, Cao Yiming, Yu Ping, Li Hongyu and Wang Xiaozhuang were invited to evaluate the correlation between each topic in the *Questionnaire on the Level of Mathematics Learning Strategies for Junior High School Students* and its respective dimensions (Expert Consultation Questionnaire) See Appendix 5), and calculate the content validity of the questionnaire based on the expert evaluation results, according to the results, the consistency level among the four evaluators is

0.84, indicating that there is good consistency among these evaluating factors. The content validity index of the questionnaire item level is shown in Table 4.2.2:

Table 4.2.2 Content Validity Index of Formal Questionnaire

Number of experts	Number of experts with a score of 3 or 4	Item number	I-CVI	Pc	K*	Evaluation
4	3	7	0.750	0.250	0.670	Good
	4	29	1.000	0.063	1.000	Excellent

There are 28 questions in the questionnaire being unanimously approved by experts, which accounts for 81% of the total number of questions, indicating that each question has good content validity; calculating the average I-CVI value of each question, it can be obtained that the content validity of the questionnaire, the S-CVI/Ave is 0.95, reaching the standard of 0.90, indicating that the *Mathematics Learning Strategies Scale for Junior High School Students* has good content validity.

According to Psychometric related theories, there should be a medium to high correlation between various dimensions of the questionnaire, and each dimension should have a high correlation with the total dimension. If the correlation between the dimensions and the total dimensions is higher than the correlation between the dimensions, it indicates that the dimensions are relatively independent, the structure validity is better; otherwise, the structure validity is poor.

Table 4.2.3 Correlation coefficients between each dimension of the questionnaire and that between each dimension and the learning strategy

	Mathematics Cognitive Strategies	Mathematics Meta-cognitive Strategies	Mathematics Resource Management Strategies	Mathematics Learning Strategies
Mathematics Cognitive Strategies	1			0.942**
Mathematics Meta-cognitive Strategies	0.804**	1		0.915**
Mathematics Resource Management Strategies	0.821**	0.758**	1	0.929**

*Remarks: ** means that there is a significant correlation at a significance level of 0.01 (two-sided).*

Through the observation of the data in Table 4.2.3, it is found that there is a significant correlation among the three dimensions of the questionnaire. The Pearson correlation coefficient between the three dimensions is between 0.75 and 0.83, and the total mathematics learning meta-cognition questionnaire is related to the Pearson correlation coefficient of each dimension. Between 0.90-0.95. The Pearson correlation coefficient between each dimension and the total questionnaire is higher than the correlation coefficient between each dimension, which means that the compiled questionnaire has good structural validity.

4.3. Establishment of the scale

In the *Mathematics Learning Strategy Scale for Junior High School Students*, mathematics learning strategies were divides into three dimensions: mathematics cognitive strategies, mathematics meta-cognitive strategies and mathematics resource management strategies. The details of the scale development are shown in the following three aspects:

1. The number and content of questions. A total of 36 questions were set in the *Mathematics Learning Strategy Scale for Junior High School Students*. The content of the questionnaire is consistent with the characteristics of junior high school students' mathematics learning, which helps prevent students from being distracted due to answering questions for a very long time, leading to distortion in data collection, and simultaneously ensuring the authenticity of the collected data.
2. Expression of questionnaire and instruction. In the compilation of the "Math Learning Strategies Scale for Junior High School Students", in order to clarify the question, words indicating frequency (such as "rarely", "frequently", etc.) were avoided, and definition of options in each level of the item is added to the instruction.
3. Verification factor analysis of the scale. In the compilation of the *Mathematics Learning Strategy Scale for Junior High School Students*, in order to better test whether the various topics of the scale and the theoretical model of the concept have a good fitting effect, sample data different from those in the verification factor analysis were adopted for verification factor analysis.

The questionnaire was developed by combing through the literature and combining expert opinions to construct a model for the initial version of the Mathematics Learning Strategies Scale, which was tested and revised several times to obtain the second, third and fourth versions of the scale respectively. Based on the test data of the fourth version, the survey model was revised to establish the structural model of the scale. A total of 36 questions were contained in *Mathematics Learning Strategies Scale for Junior High School Students*, which were divided into 3 dimensions and polygraph questions. The specific distribution of these questions is shown in Table 4.3.1.

Table 4.3.1 Item Distribution of Mathematics Learning Strategy Scale for Junior High School Students (4th Edition)

First-level dimension	Second-level dimension	NO.	Number of questions
Mathematics Cognitive Strategies	Retelling Strategy	3,10,24,27	4
	Elaboration Strategy	2,8,17,28	4
	Organize Strategy	1,7,30	3
Mathematics Meta-cognitive Strategies	Planning Strategy	26,31,33,36	4
	Monitoring Strategy	13,15,18	3
	Feedback-Adjustment Strategy	9,23,32	3
Mathematics Resource Management Strategies	Time-management Strategy	4,19,25	3
	Environment-management Strategy	16,21,22	3
	Mood-management Strategy	6,12,29	3
	Help-seeking Strategy	5,20	2
Polygraph Test		11--34,14--35	4

Total	36

Remarks: No.11 and NO.34; NO.14 and NO.35 are two pairwise lie-detect items

5. Development of an intelligent assessment system for mathematical learning strategies

Based on the above learning strategy scales for junior secondary school students, two intelligent assessment tools have been designed and developed based on different scenarios, namely the Individual Student Edition S1.0 and the Integrated School Edition X1.0, which provides reports and recommendations for individual students and schools and districts as a whole.

The software is divided into three modules: the first module is the basic information collection module, the second module is the scale data collection module and the third module is the results and recommendations output module. The research team used technology to improve the compatibility of the scale by upgrading the previous paper-and-pencil test to a combination of online and offline tests; using technology to improve the practicality of the scale by providing timely feedback to students on the test results and giving them strategies for improvement; and using technology to improve the convenience of the scale by collecting the results of each student's test in a coordinated manner to provide a basis for overall proficiency testing in schools and districts.

The software integrates the various dimensions of the mathematics learning strategy scale for junior high school students and the level of learning strategy levels in each region. After uploading the overall data collected by the individual student version S1.0, it can output a customized document for each student with the overall score, First-level dimension score rate, First-level dimension level radar graph, and detailed response recommendations in an intelligent and batch-oriented way .The software uses technology to accurately measure students' level of mathematical learning strategies, enhance students' knowledge of their own level of mathematical learning strategies and greatly improve the quality of their mathematical learning.

6. Conclusion and Discussion

Since Pintrich, Mckeachie et al. (see [6]) developed the MSLQ, scales for measuring students' learning strategies have evolved, but there is a wide variety of dimensional divisions, and this complexity has posed some problems for researchers in selecting and using the scales. According to a literature review of the direction of learning strategy measurement, the learning strategy-related scales developed in recent years are mostly universal and general scales, and there is a lack of special scales for mathematics subjects and junior high school students.

Therefore, this research aims to achieve two goals. One is to establish a dimensional model and operational definition of mathematics learning strategies; the other is to make an authoritative mathematics learning strategy scale suitable for junior high school students based on the established model.

Therefore, this study aims to achieve three objectives: firstly, to establish a dimensional model and operational definition of mathematics learning strategies; secondly, to produce an authoritative mathematics learning strategies scale for junior secondary school students based on the model developed; thirdly, to develop an intelligent assessment system to provide convenient, fast and accurate conditions for the practical application of the Mathematics Learning Strategies Scale for junior secondary students, and provide students with targeted countermeasure suggestions based on accurate measurements..

In this research, 81 items (belonging to three main dimensions) were first established. Based on the significant difference test, exploratory factor analysis, and expert guidance and suggestions, the items were deleted and adapted to make the items, reduced 81 items to 36 items (belonging to 10 types of sub-dimensions, 3 types of main dimensions), and then the *Mathematics Learning Strategy Scales for Junior High School Students* were established. The reliability of this scale is tested by Cronbach's α coefficient, showing that the scale is very reliable.

Furthermore, verification factor analysis was adopted in this study to evaluate and test the established model. After the model was revised, it was found that all fitness indexes were within the acceptable range, indicating that the structural model was verified. The development process of the "Mathematics Learning Strategy Scale for Junior High School Students" is scientific and objective, with good reliability and validity indicators, and can be used as an effective tool for investigating and evaluating the level of junior high school students' mathematics learning strategy.

Finally, the "Intelligent Batch Assessment of Mathematics Learning Quality for Primary and Secondary Students - Learning Strategies" software, S1.0 for individual students and X1.0 for schools, was developed using the well-developed Mathematics Learning Strategies Scale for junior secondary students. After simulation tests and field applications in Tianjin, Chongqing, Qinghai Province and Henan Province, the software has shown very good results in helping individual students to improve their mathematics learning strategies and learning quality, and in helping schools and districts to accurately control the weaknesses in mathematics education development.

In the follow-up of this study, we will continue to optimize the software, provide students with the measurement of mathematics learning level, provide suggestions for students to learn mathematics according to the measurement results, combine it with curriculum compilation, and make contributions to curricular choices and assessment practices based on experimental data.

Appendix 1

The Mathematics Learning Strategy Scales for Junior High School Students

Dear students:

To explore some of the thoughts and feelings of junior high school students in the process of mathematics learning, we invite you to participate in this survey. Thank you for your cooperation with this survey.

Specific requirements are as follows:

1. Please fill in or select the appropriate answer according to your actual situation. Note that each question needs to be answered, and only one answer can be selected
2. There are five options in each question: A, B, C, D, and E, and the meaning of each alternative answer is as follows

A: Very consistent: it does not mean that the situation described by the fan is always happening to you, but it means that the fan is consistent with you in almost all situations
B: Consistent: it means that this statement is consistent with you under normal circumstances
C: Uncertain:half of the cases where this statement is consistent with you
D: Inconsistent: this statement is inconsistent for you under normal circumstances.
E: Very inconsistent: the statement is inconsistent to you in almost all cases
3. There is no right or wrong answer to the following questions, and the answer results are only for scientific research and not as other basis;
4. The results of this survey will be answered anonymously. We expect to keep the results of the answers absolutely confidential. Please be sure to answer every question carefully and truthfully. Your response is very important to our research.

Basic Information

School: Class: Gender: Age:

Survey item

NO.	Items	Options
1	I will sort out the difficulties in each section of junior high school mathematics.	A B C D E
2	When learning a new mathematical concept, I would contemplate the difference and connection between it and the concept I previously learned.	A B C D E
3	When encountering complex geometric problems, I will draw to assist in the solution.	A B C D E
4	In the process of junior high school mathematics, I can arrange the study time and rest time reasonably.	A B C D E
5	After entering junior high school, I will ask the teacher some math problems.	A B C D E
6	When encountering math problems, I encourage myself to persist in thinking more.	A B C D E
7	I will summarize the question types of the math exams in junior high school.	A B C D E
8	When encountering an unfamiliar mathematical problem, I try to expect it to be transformed into a familiar problem. For example, when solving a system of ternary linear equations, it will be transformed into a familiar system of linear equations in two unknowns, and then solved.	A B C D E
9	I ponder how I can improve my math scores.	A B C D E
10	When studying mathematics, I will mark important content.	A B C D E
11	I hate taking math class.	A B C D E
12	I was able to adjust my mentality during the junior high school math learning process, so that I was neither too slack nor too nervous.	A B C D E
13	I compare the differences in learning behavior between myself and mathematics top students to find ways to improve mathematics	A B C D E

	performance.	
14	Learning mathematics is helpful to solve problems in real life.	**A B C D E**
15	In math class, I will avoid being distracted.	**A B C D E**
16	I arranged the mathematics study plans in junior high school in an orderly manner.	**A B C D E**
17	Magnet to complex mathematical problems. I will divide it into a small problem.	**A B C D E**
18	In order to check whether I have mastered the mathematical knowledge I have learned, I will set up questions.	**A B C D E**
19	After entering junior high school, I can arrange time reasonably and complete math homework on time.	**A B C D E**
20	I will discuss mathematics issues with my classmates.	**A B C D E**
21	I will create a good environment for students to learn mathematics to improve the efficiency of mathematics learning.	**A B C D E**
22	I organized the math test papers in junior high school in an orderly manner for easy review and reference.	**A B C D E**
23	I reflect on whether my mathematics learning method is effective.	**A B C D E**
24	I will describe mathematical concepts in a variety of ways such as text language, graphic language and symbolic language.	**A B C D E**
25	In junior high school mathematics study, I can effectively use the break time between classes.	**A B C D E**
26	Since entering junior high school, I have perfected my mathematics half-study plan based on actual needs.	**A B C D E**
27	I will memorize important mathematical content repeatedly.	**A B C D E**
28	When I find similar mathematical knowledge, I will compare their similarities and differences, like concepts of monomials and polynomials.	**A B C D E**
29	While solving mathematics problems, I will select the appropriate method of solving the problem according to the question type.	**A B C D E**
30	I will sort out the key points of each mathematics knowledge in junior high school.	**A B C D E**
31	I will preview and figure out the key content so that I can focus on listening to the teacher's instructions in class.	**A B C D E**
32	When I know the math test scores, I will think about why there are fluctuations in my performance.	**A B C D E**
33	As the math test papers being issued. I will first have a rough look at what types of questions are included in the test paper.	**A B C D E**
34	I like taking math class.	**A B C D E**
35	Studying mathematics does not help solve real-life problems.	**A B C D E**
36	Before taking math class, I will figure out the difficulties that I will learn so that I can pay attention to teachers' instructions in class.	**A B C D E**

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