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Research on Mathematics Extracurricular Activities in Middle School in China

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Mathematics extracurricular activities are not only conducive to students' all-round development, but also a beneficial supplement to the current classroom teaching. In this study, 30 pieces of literature on mathematics extracurricular activities in middle school from 1993 to 2022 were selected from the database of China Knowledge Network（CNKI）as the data source. This paper qualitatively analyzed the literature to summarize and sort out the previous research and found that: (1) Current domestic studies mainly focus on the following four aspects: classification, forms and content of mathematics extracurricular activities; organizing principles of mathematics extracurricular activities; issues needing attention in mathematics extracurricular activities; evaluation of mathematics extracurricular activities. (2) The forms of mathematics extracurricular activities are various, mainly including extracurricular mathematics groups, mathematics special lectures, etc. The principles of organizing mathematics extracurricular activities have been studied very thoroughly. Previous studies have mainly discussed the issues needing attention from activity implementation, content selection, students and teachers. There are few studies on the evaluation of mathematics extracurricular activities. (3) Researchers mainly collected data based on

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observation and experience, and some researchers draw conclusions based on theoretical speculation or teaching experience, lacking strict experimental verification. Therefore, future research needs to adopt more scientific research tools, expand the scope of research, increase verification research, and give more scientific and effective suggestions, to make this research more comprehensive, systematic and profound.

Keywords: Mathematics extracurricular activities; middle school; students; mathematics education.

1. INTRODUCTION

The explanation of mathematics extracurricular activities in *Educational Dictionary* is: "In addition to classroom teaching, various activities related to mathematics learning that students participate in. Properly organizing and attracting students to participate in mathematics extracurricular activities can expand students' knowledge field, cultivate their interest in learning mathematics, and develop their mathematical talents" [1]. In recent years, with the continuous development of basic education in China, mathematics extracurricular activities have gradually played an important role in education. Since "Mathematics Curriculum Standards for Full Time Compulsory Education (Experimental Draft)" [2] explicitly included "mathematical activity experience" in the curriculum objectives for the first time, it has continued to emphasize "basic activity experience". After the promulgation of the "double reduction" policy in 2021, one of the measures is to "improve the level of after-school services to meet the diverse needs of students" [3], which puts forward higher requirements for mathematics extracurricular activities. So far, there have been many studies on mathematics extracurricular activities, but no studies have analyzed and evaluated them. To find out the current situations, deficiencies, and gaps in this direction, the author analyzes the previous relevant research, and tries to provide experience and reference for teachers' organizations and students' participation, so as to promote the continuous development and deepening of this direction.

The main research questions in this paper are as follows:

(1) What are the main aspects of the current research on the mathematics extracurricular activities in middle school, and what are the results of each aspect?
(2) What are the deficiencies and gaps in the current research on mathematics extracurricular activities in middle school?

2. METHODOLOGY

2.1 Data Source

This paper adopts the method of literature analysis and takes the literature in the database of CNKI as the data source. CNKI provides a multidisciplinary database and is a powerful retrieval tool. It contains a wealth of documents and has great academic impact. Therefore, it is selected to ensure the reliability and persuasiveness of the research. The literature on mathematics extracurricular activities from 1990 to the present in CNKI was selected as the data source for this study.

2.2 Data Collection

To avoid the literature omission, the author searched in different ways. Data collection is divided into three steps: Firstly, the author searched with *mathematics extracurricular activities* as the subject words from core journals. After reading through and screening, 2 pieces of literature were selected. Secondly, taking *mathematics extracurricular activities in middle school*, *mathematics expansion activities that are not in primary school*, *the second classroom of middle school mathematics as the search item*, a total of 179 results were retrieved. After excluding the literature irrelevant to the subject of this study, and the remaining 20 articles were selected. Finally, the author made a comprehensive search on the theme of mathematics extracurricular activities, and 8 articles were added. At the same time, the publication time of all references is limited to after 1990. In the end, there are 30 pieces of literature were sorted and analyzed.

2.3 Data Collation

This study is a narrative literature review, and the selected literature was analyzed qualitatively. Firstly, the above literature is sorted, numbered and read in detail, and then the research content, research results and research methods mentioned therein are recorded. Finally, the

results are counted and summarized. The research procedure and main results of this paper are shown in Fig. 1.

3. RESULTS

After sorting out and analyzing the previous studies, it is found that the current domestic research on mathematics extracurricular activities in middle school mainly focuses on the following four aspects: Classification, forms and content of mathematics extracurricular activities; organizing principles of mathematics extracurricular activities; issues needing attention in mathematics extracurricular activities; evaluation of mathematics extracurricular activities.

3.1 Classification, Forms and Content of Mathematics Extracurricular Activities

With the advancement of the research on mathematics extracurricular activities, researchers classify the mathematics extracurricular activities according to different standards and introduce different forms and contents. Their views are as follows:

Zhou divided mathematics extracurricular activities into six categories according to the content of extracurricular activities, including competition training activities, fun quiz activities, reading activities, experiencing base activities, outdoor practice activities and inquiry writing activities. And he introduced six specific ways, namely, listening to lectures, taking part in a math contest, answering competitions, entering the base, extracurricular reading and practical work [4].

According to the content characteristics of the junior high school mathematics textbook published by the People's Education Press, the students' physical and mental development level, the teaching resources of the school and the requirements of the curriculum goals, Bai divided the mathematics extracurricular activities into eight categories, including mathematical games, mathematical lectures, hands-on production, life practice, mathematical competitions, interesting topic discussions, teaching and training, and mathematical stories [5].

Xie divided mathematics extracurricular activities into explanation type, game type, hands-on type, story type, mathematical language type, mathematics challenge arena type and mathematics debate type according to the forms of activities [6].

Deng analyzed mathematics extracurricular activities from three categories: mathematics interest activities, research learning activities and mathematics fun competitions. Among them, the forms of mathematics interest activities include simple measurements, making teaching models, practical drawing design, statistical investigations, etc. The forms of research learning activities include special lectures on mathematics, organizing students to conduct research on a topic, etc. [7].

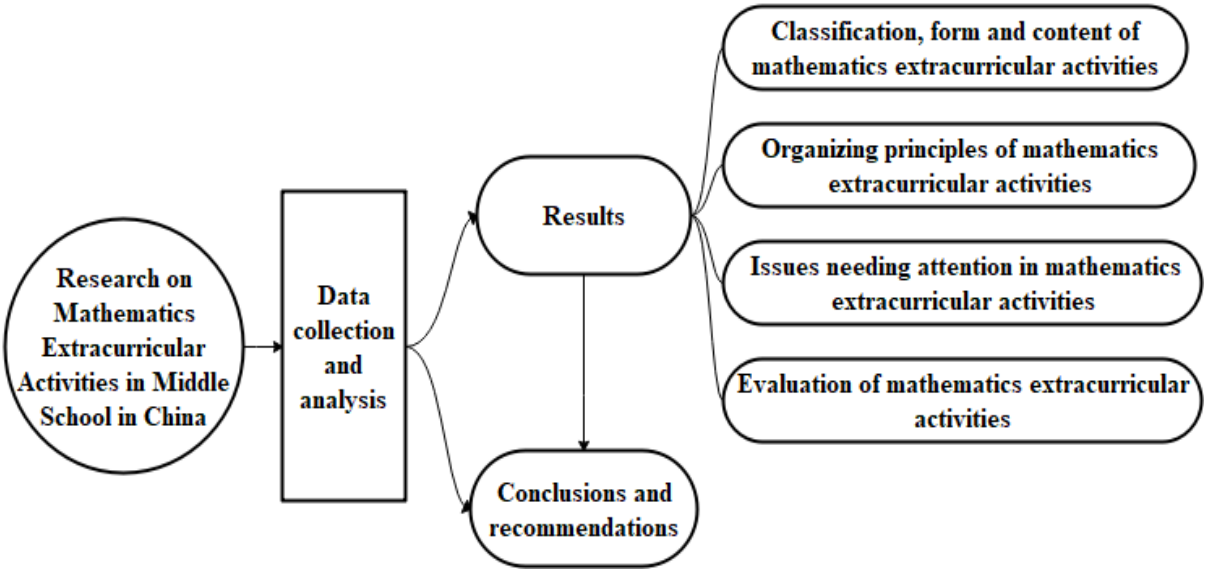

Fig. 1. Research procedure and main results

Wang and Guo believed that the content of mathematics extracurricular activities should be extended from the content of textbooks, and divided mathematics extracurricular activities into practical operation and theoretical summary. Among them, practical operations include area measurements and calculations, indirect measurement of tree height or building height, etc. Theoretical summary, such as: several judgments of parallel lines, function problems in life, etc. [8].

Shen pointed out that there are two types of mathematics extracurricular activities: in-class mathematics activities and mathematics activities out of the class, which vary according to the time and space of the activities. In-class mathematics activities are carried out in the classroom, mainly in three forms: discussion and research, reading and hands-on operation. The mathematics activities out of the class can be carried out in the space outside the classroom when there is no class. There are mainly five forms: combining school-based courses, mathematics elective courses, establishing interest groups, establishing mathematics gardens and conducting investigations and research [9].

According to the number of participants, Qin divides mathematics extracurricular activities into collective activities, group activities and individual activities. He believed that group activities are more practical and effective. The activities include the production of mathematical teaching aids, mathematical extracurricular reading, mathematical garden and mathematical competitions [10]. Cao agreed with him. In addition, she also mentioned four types of mathematics extracurricular activities, namely, social practice activities, science and technology activities, manual activities and labor lessons. Mathematical social practice is based on the mutual transformation of theory and practice. Science and technology activities can be divided into two categories: one is the scientific research groups participated by students interested in mathematics, and the other is the technical group aimed at learning mathematical knowledge and skills. Manual activities can be carried out in combination with labor technology courses. Labor class is not only a part of classroom teaching, but also an independent extracurricular activity [11].

Wang believed that when conducting mathematics extracurricular activities, group activities such as debates, mathematics speech competitions, and mathematics story meetings can be organized. Social interaction activities such as summer camps, winter camps and investigations can also be designed. Appreciation and understanding course of mathematical culture can also be held to introduce mathematicians and mathematical history or related disciplines of mathematics, such as cryptography, logic and computers [12].

Wang and Xu mentioned that mathematics extracurricular activities mainly take the form of mathematics interest groups and mathematics journals. The former can be held in groups to listen to special reports and participate in mathematics competitions, subject seminars, mathematics production and other activities. The latter includes mathematical posters, "mathematical mailboxes" and so on [13,14]. Chen, Ma and Yin believed that in addition to the above two main forms of mathematics extracurricular activities, mathematics elective courses were added [15-17]. Zhang, Liu and others had almost the same view as Chen and others. They just changed the mathematics elective course to mathematics lectures. Although they are called differently, their main contents are also to introduce a certain branch of mathematics, a special topic, or introduce new progress, new disciplines and new mathematical ideas in mathematics [18-21]. Zhou believed that the forms of mathematics extracurricular activities in middle school should also include the establishment of advanced mathematics classes or mathematics schools, so as to help broaden the scope of knowledge learned in class [22].

Zhang pointed out that mathematics extracurricular activities should be held according to the grade, and different activity groups should be set up according to the degree, interest and desire of students, such as mathematics interest groups, mathematics competition groups, mathematics research study groups, mathematics practice groups, etc. And different activities should be carried out in each group, such as interesting mathematics activities, competitions, exchange activities, mathematics practice activities, etc. [23].

Jiang contended that the forms of mathematics extracurricular activities mainly include expanding teaching and learning content, making teaching aids, reading and writing essays after class, mathematics competition lectures and editing mathematics tabloids [24]. He believed that mathematics extracurricular activities in

middle school can take the form of holding special lectures, exchanging learning experiences, introducing mathematics extracurricular reading publications, publishing mathematics learning corners, exchanging mathematics papers, and conducting mathematics competitions [25]. The forms of activities mentioned by He in his research include origami, model making, mathematical practice, simulation experiments, social investigations, etc. [26]. Li took the second class as a supplement to the first class with the goal of promoting in-class learning. Through activities such as math stories, creating activity scenarios, math experiments, math competitions, and summarizing mathematical models, the acquisition of in-class knowledge is promoted [27].

In previous studies, there was no unified standards and results for the classification of mathematical extracurricular activities. Many researchers also introduce the specific forms of activities in their classification studies, which are various. From different dimensions, the forms of activities mentioned by researchers may include each other or overlap. For example, many researchers take extracurricular math groups as a form of activity, and then carry out activities of different contents on this basis. Some researchers, considering the activities themselves, think that the forms of activities include special lectures, mathematical competitions, etc. Although there are no standard and complete results among many research conclusions, many forms have been mentioned by most researchers, such as extracurricular mathematics groups, mathematics seminars, mathematics competitions, writing papers on research topics, mathematics journals, hands-on production of mathematics teaching aids and models, etc.

3.2 Organizing Principles of Mathematics Extracurricular Activities

Different researchers have given different organizing principles of mathematics extracurricular activities and given the contents of each principle. Their views are as follows:

Wang proposed that the following three principles should be implemented in the mathematics extracurricular activities: the practical principle, the scientific principle and attention to curriculum structure design. The practical principle is to give students full opportunities to practice and get exercise in mathematics extracurricular activities. The practical principle mainly includes activity, process, openness, subjectivity and constructiveness. The scientific principle mainly refers to that students' level and objective conditions should be fully considered in the content and forms of teaching activities. Scientific implementation of mathematics extracurricular activities mainly includes scientific activity content, scientific activity forms, scientific activity organization, scientific activity guidance and scientific activity evaluation. The curriculum structure design mainly includes macro design and micro design. On the macro level, it is mainly about the purpose, content, activity patterns, final evaluation method and management means of the activity curriculum. On the micro level, it is mainly about the design of the specific plot, process and other details of the activity class [12].

Zhou put forward four principles: the principle of moderate design, interest, hierarchy and the unity. The principle of moderate design is that the difficulty of activities should be suitable for students' practice field. The principle of interest is to choose the hot issues in junior high school mathematics teaching and the issues that students are interested in in order to attract students to participate actively. Hierarchical principle refers to the design of diversified mathematical activities to adapt to students' differences, so that students at different levels have different display forms. The principle of unity is to unify the content and objectives of activities as much as possible, so as to facilitate the evaluation of students [28].

Zhang and He both listed seven basic principles with reference to the *Education Dictionary*: the principle of directivity, voluntariness, initiative and independence, and the activity, the principle of conforming to the age and individual characteristics of students, the principle of teaching students in accordance with their aptitude, and the principle of adapting to local conditions.

The principle of directivity, that is, the content of activities should conform to the educational policies and the goal of middle school mathematics education. The principle of voluntariness is that students could voluntarily participate according to their interests and choose according to their own intellectual strengths. The principle of initiative and independence wants students to be taken as

subjects, so that students can self-select, self-design, self-organize, self-evaluate, and exert their autonomy and independence according to their hobbies and interests. The principle of activity is to attach importance to the process of students' mathematical activities and pay attention to the combination of mathematical understanding activities and practical activities. The principle of conforming to the age and individual characteristics of students, that is, the content and forms of extracurricular activities can be accepted by students. The principle of teaching students in accordance with their aptitude refers to treating students at different levels differently. On the principle of adapting to local conditions, it is necessary to make use of favorable conditions according to the economic and cultural conditions of various places and the actual situations of students [23,25].

Li believed that mathematics extracurricular activities should follow the principles of foundation, teaching students in accordance with their aptitude, systematicness, motivation, creativity and effectiveness.

The main content of the foundational principle is that the content of mathematics extracurricular activities should be selected from the important knowledge and ideas in middle school mathematics, and basic problems should be paid attention to in the activities. The principle of teaching students in accordance with their aptitude means that the content should be determined according to the actual situations of students, and students should gradually master it in stages and levels. The systematic principle is to make overall arrangements and careful plans for the extracurricular activities throughout the senior high school period, with goals and requirements at all stages and in general. The principle of motivation is to give students appropriate evaluation and encourage them to work hard, referring to the psychological and personality characteristics of high school students. Mathematics extracurricular activities should focus on the cultivation of students' creative thinking ability, which is the main content of the creative principle. The principle of effectiveness is that mathematics extracurricular activities should not be mere formality, and efficiency should be improved [29].

Gao proposed that mathematics extracurricular activities should follow the following principles: ideological, planned, basic and hierarchical, interesting and diversified, student-centered and practical, and regular principles. The ideological principle is that moral education should always be put in the first place in mathematics extracurricular activities, and patriotism and Chinese culture should be permeated. The principle of planning requires us to carefully consider the content of activities, schedules and other aspects. The mathematics extracurricular activities should be extended on the premise of mastering the basic knowledge in class, and the content of the activities should be designed from simple to deep. The above is required in the basic and hierarchical principles. The principle of interest and diversification is that the forms and content of activities should be novel and diverse in order to maintain students' interest in learning mathematics. The principle of taking students as the main body and connecting with reality is that students' research and experiment are the more important in activities, and teachers only play a guiding role. The principle of regularity is reflected in the fact that the good results of activities require long-term persistence [30].

Bai proposed to adhere to seven principles, including the principle of combining classroom teaching, the principle of combining dominance with subjectivity, the principle of ideology, the principle of foundation and hierarchy, the principle of voluntariness, the principle of classified guidance and the principle of adapting measures to local conditions. Regarding the first two principles, he believed that mathematics extracurricular activities should refer to textbooks and combine with classroom teaching. Students' subjective initiative should be exerted in the activity, and the selection of activity content should refer to the students' existing life experience. As for the third and fourth principles, they are almost consistent with the connotation of the principle of the same name given by Gao. The last three principles are similar to those proposed by Zhang and others [5].

Wang and Guo proposed that the design of mathematical extracurricular activities should be specific, operable, enlightening and interesting. In addition, it is necessary to regularly display results and pay attention to students' self-evaluation [8]. Yang ZF and Yang ZZ believed that the second class activities of mathematics should be multi-level, multi-channel and interesting. The scientificity and extension of knowledge should be emphasized. Activities should be practical, social and flexible. The holding of the event requires multi-party cooperation to make the event both stable and open [31].

In previous studies, the principles of organizing mathematical extracurricular activities have been very comprehensive. All researchers have paid attention to the principles of content selection, and they have different views on content selection, but their views are just different in emphasis and will not completely exclude each other. Most researchers also emphasized the autonomy and practicality of students and the need to treat students differently. In addition, the principles of overall arrangements, guiding ideology and realistic conditions are also concerned by most researchers. Only one researcher mentioned that the activities should be unified in content and objectives to facilitate evaluation.

3.3 Issues Needing Attention in Mathematics Extracurricular Activities

The previous researchers discussed the issues needing attention in mathematics extracurricular activities from the following four aspects: activity implementation, content selection, students and teachers.

On the implementation of activities: (1) Put students first, avoid the situation that teachers are the center and students participate passively [8,19,32]. (2) In order to reduce the burden on students, mathematics extracurricular activities should not be too frequent, and each activity should be of high quality [9,20]. (3) Avoid becoming a mere formality and wasting time. Mathematics extracurricular activities cannot be a reasonable excuse for making up after class in exam-oriented education. The educational policies should be truly implemented [19,31,33].

In terms of content selection: The activities should be suitable for the actual situations of middle school students' psychology or knowledge level and should also be linked to the content in the current mathematics class. Based on curriculum standards and textbooks but the activities should not be too much bound by them. The content should be systematic and interesting, easy for students to master, and easy for teachers to check. The content to be learned at the back of the textbooks should not be put in front as an activity [9,13-16,19,20,29,32,33].

As for students: The event is open to all students while maintaining a voluntary principle. Students who are engaged or unengaged are concerned. First ensure that they meet the basic requirements of in-class learning, and then help students choose activities that are suitable for them. In addition to training students in mathematics, it is necessary to pay attention to the character of students and overcome the superiority and pride of some students [13-16,19,20,29].

As for teachers: Most teachers lack professional knowledge and reference experience in organizing mathematics extracurricular activities and have limited guidance. Education administrative departments and school leaders should regularly organize training in this area, and teachers should constantly update their educational concepts [9,31].

3.4 Evaluation of Mathematics Extracurricular Activities

The evaluation of mathematics extracurricular activities is an integral part of educational evaluation. Through the evaluation, reasonable feedback can be given on the implementation, process, results and value of mathematics extracurricular activities. In previous studies. The main points of evaluation are as follows:

Wang believed that evaluation plays a good role in promoting students' participation in extracurricular activities and emphasized the role of teachers' evaluation. He advocated that all students should be evaluated at four levels: excellent, good, average and needing to be strengthened [13].

Bai also stressed the importance of evaluation, mainly teachers' evaluation of students. This should be combined with formative evaluation and final evaluation. Attention should be paid to the process and effect of activities. In addition, evaluation can also be in the forms of student self-assessment and student peer evaluation [5].

Referring to *Activity Curriculum Theory and Practice* written by Gao, He gave a more complete evaluation system for mathematics extracurricular activities and divided it into organizational work evaluation and students' activity evaluation. The former evaluates school leaders and teachers, while the latter evaluates students. The evaluation of both components takes into account two aspects: overall evaluation and thematic learning activity evaluation. And he believed that the evaluation on students' activities are the main part of mathematics extracurricular activity evaluation. In

particular, he emphasized the importance of process evaluation, focusing on the learning process of students [25].

There are few research on the evaluation of mathematics extracurricular activities, but many researchers have emphasized the importance of evaluation. Wang and Bai only paid attention to the evaluation of students, the main body of the activity. He built a relatively complete evaluation system, believing that all groups involved in the activity should be evaluated. In particular, for the evaluation of students, Wang emphasized the role of teachers' evaluation in promoting students' development. He Ming paid more attention to the role of students in the collective, and he believed that the evaluation should be conducted jointly by students themselves and the collective. Bai integrated two perspectives.

4. DISCUSSION

Current domestic studies mainly focus on the following four aspects: classification, forms and content of mathematics extracurricular activities; organizing principles of mathematics extracurricular activities; issues needing attention in mathematics extracurricular activities; evaluation of mathematics extracurricular activities.

As for the classification, forms and content of mathematics extracurricular activities, previous researchers classified them according to different standards. Some researchers directly introduced the forms of activities, and their views intersected with each other. The forms of activities mentioned by most researchers include extracurricular mathematical groups, mathematical lectures, mathematical competitions, research projects and writing papers, mathematical journals, and hands-on production of mathematical teaching aids and models. Although these forms are not complete, they are recognized by most researchers and have certain practicality and effectiveness. In addition, there is still little research on how to organize specific forms of activities, lacking systematic activity design and implementation schemes.

As for the principles of organizing mathematics extracurricular activities, all researchers have paid attention to the principles that should be followed in content selection, and each researcher has different opinions. Therefore, the selection of activity content is a very important part. In addition, most researchers also emphasized the autonomy and practicality of students and should treat students differently. Only one researcher mentioned unifying the content and objectives of the activity as much as possible to facilitate evaluation. In terms of breadth, the organization principles of mathematics extracurricular activities mentioned by the researchers have been very comprehensive, involving all aspects and groups. In depth, the refinement of each principle and the guidance of practice still need to be further strengthened.

The previous researchers discussed the issues needing attention in mathematics extracurricular activities from the following four aspects: activity implementation, content selection, students and teachers. Almost all researchers agree that the content of activities should be derived from class knowledge and higher than its level, and students should voluntarily participate on the premise of ensuring normal learning. These precautions reflect the educational environment under the current exam-oriented education in China, and efforts are still needed to truly play the role of extracurricular mathematics activities. There are few research on the evaluation of mathematics extracurricular activities, but the importance of evaluation cannot be ignored.

There are still some deficiencies in previous studies. First of all, most researchers paid more attention to the forms of mathematics extracurricular activities, and less attention to the selection of content. Secondly, previous studies rarely considered regional differences. The situation will be different because of the differences in cities, schools and conditions. Finally, most of these studies stay at the theoretical level. Most researchers draw conclusions based on daily observation and personal experience, lacking strict experimental verification. It can be seen that the current research is not very strict and scientific.

There are some gaps in previous studies. Firstly, the researchers focus more on students, but lacks requirements for other aspects such as schools, families, society, education departments, etc. Secondly, the previous research has not yet given a systematic design and practice modes of mathematics extracurricular activities. Thirdly, domestic

research lacks localized research tools and systematic analysis framework.

5. CONCLUSIONS AND RECOMMENDATIONS

By analyzing the previous research on mathematics extracurricular activities, the following conclusions are drawn:

(1) Current domestic studies mainly focus on the following four aspects: classification, forms and content of mathematics extracurricular activities; organizing principles of mathematics extracurricular activities; issues needing attention in mathematics extracurricular activities; evaluation of mathematics extracurricular activities. There are many kinds and forms of mathematics extracurricular activities. Researchers have different views from different angles. Most researchers have mentioned extracurricular mathematics groups, mathematics lectures, etc. As for the organization principles of mathematics extracurricular activities, the previous research has involved very comprehensive aspects, and their views are different, but not completely contradictory. Almost all researchers have paid attention to the principles of content selection in mathematics extracurricular activities. The previous researchers discussed the issues needing attention in mathematics extracurricular activities from the following four aspects: activity implementation, content selection, students and teachers.

(2) There are some deficiencies and gaps in previous studies. Researchers mainly collected data based on observation and experience, and draw conclusions based on theoretical thinking or teaching experience, lacking strict experimental verification. For the research of mathematics extracurricular activities, more attention is paid to the forms of activities, less to the content, more attention is paid to students, and there is a lack of requirements for other subjects such as schools, families, society, education departments, etc. In addition, geographical differences are rarely considered. Therefore, these aspects should be expanded. The research in this direction has not yet provided the system design and practice methods, and lacks the local research tools and analysis framework, which should be improved.

Therefore, based on current research, future research needs to adopt more scientific research tools, more reasonable analysis framework, expand research scope, increase validation research, and give more scientific suggestions. So that the research on mathematics extracurricular activities is more comprehensive, systematic and profound.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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