



Research on Online Mathematics Teaching in Chinese Colleges

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Authors' contributions

This work was carried out in collaboration among all authors. Author CS designed the study, managed the literature searches, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author ZY managed the analyses of the study. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJESS/2021/v18i430446

Editor(s):

(1) Dr. Vlasta Hus, University of Maribor, Slovenia.

Reviewers:

(1) Baaziz Termina, Morocco.

(2) Najwa Mordhah, Yanbu University College (Women's Campus), KSA.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/69298>

Review Article

Received 11 April 2021

Accepted 21 June 2021

Published 25 June 2021

ABSTRACT

Aims: This paper was carried out to understand the situation and implementation effect of mathematics education and teaching work in colleges under the epidemic situation, grasp the problems and solving strategies in the practical processes, provide new ideas for mathematics education researchers and new inspiration for optimizing online teaching.

Methodology: The researcher checked all references that met the research criteria and finally identified 37 papers as research papers and summarized all the achievements by taking notes.

Conclusions: It is found that the current research results for college mathematics online teaching can be roughly divided into three types: college mathematics online teaching models and platforms, implementation strategies, and evaluation reflections. (1) Current domestic studies mainly focus on the selection of online teaching platforms and models, the implementation strategies of college mathematics online teaching (including strategies before class, during class and after class), and evaluation and reflection (advantages, limitations, factors and optimization). Previous studies have included many achievements with a certain depth and laid a good foundation for future research. (2) Previous studies have great limitations in the selection of research methods, and lack of empirical research to strengthen persuasiveness and reliability. Secondly, although the predecessors have obtained many results, the depth and breadth are very

limited. (3) There is still a lot of room for research on this subject, such as online teaching research for other narrow higher mathematics courses, research on online teaching models suitable for students of different professional categories and ability levels, and establishing a sound evaluation system of blended learning model, etc.

Keywords: College mathematics, higher education, online teaching, COVID-19.

1. INTRODUCTION

On February 4, 2020, the document issued by Ministry of Education of the People's Republic of China pointed out that colleges should actively carry out online teaching activities based on various online course platforms to ensure the teaching progress and quality during the epidemic period [1]. Besides, according to "class suspension and non-stop learning" put forward by another document issued by Ministry of Education [2], colleges have developed online teaching programs to carry out online teaching activities based on various online teaching platforms [3]. Therefore, based on the development trend of the epidemic situation, the online teaching of mathematics in colleges has developed rapidly, and there have been many research results on the online teaching of college mathematics, but there has been no general research on this topic so far. So, this paper was carried out to summarize the previous achievements of online teaching of mathematics in colleges to grasp the problems and solving strategies in the practical processes, provide new ideas for mathematics education researchers and new inspiration for optimizing online teaching.

The research questions of this paper are as follows:

- (1) What are the achievements of the previous research on mathematics online teaching?
- (2) What are the limitations of the previous research on mathematics online teaching?
- (3) What are the blanks in the past research on mathematics online teaching?

2. METHOD

2.1 Source

The database for this study is CNKI. CNKI database is a large-scale full-text database in China, which contains all kinds of papers and materials. It is the most authoritative literature retrieval tool for national academic journals. Therefore, this database is selected to ensure its comprehensiveness and reliability based on the

integrity of its literature collection and huge academic influence in China.

2.2 Data Collection

First of all, the author took "subject" as the retrieval item, and input the strings that "mathematics online teaching", "advanced mathematics online teaching" and "university mathematics online teaching", and obtains 136 retrieval results. All the retrieved papers are screened by the following criteria: (1) the research topics are highly related to the online teaching of mathematics in colleges; (2) Online mathematics teaching research must be based on a higher education background; (3) The thesis format contains journal articles, graduation thesis or conference proceedings. After the screening, the researcher checked all references that met the above criteria and finally identified 37 papers as research materials.

2.3 Data Collation

The author summarized all the materials by taking notes, combined with research content and research questions, and found that the current research results for college mathematics online teaching can be roughly divided into three types: college mathematics online teaching models and platforms, implementation strategies, and evaluation reflections.

3. RESULTS

3.1 Practice of Online Mathematics Teaching in Colleges

3.1.1 Research objects, content, and methods

Regarding the research objects, it is found that previous research mainly differs in the choice of mathematics courses and student groups after sorting out the data. In terms of mathematics curriculum, the previous research mainly includes probability theory and mathematical statistics [4,24], advanced mathematics [5,9-10,12-17,20-21,23-26,27], discrete mathematics

[18], linear algebra [22] and other mathematical courses, while some are aimed at the college mathematics curriculum in a broad sense without clear curriculum research object [6,19,28]. For student groups, most studies focus on "college students" without classifying students, and only a few studies have clarified the types of students, such as vocational students and economic management students.

Regarding the research content, after preliminary analysis of the thesis data, it is found that the research content mainly involved two aspects: the strategies of college mathematics online teaching, and the implementation evaluation and reflection. Most of the studies have discussed the teaching scheme of mathematics online teaching in colleges [4,6,9,12]. As for the teaching programs, most of the studies summarized the activities of teachers and students from the preparation of online teaching, the process of online teaching, and consolidation and feedback after class. Previous studies have also involved the evaluation and reflection of online teaching practice. Some studies hold a positive attitude towards online teaching [13,23] and believe that online teaching can achieve the goal of the traditional teaching model [4]. Most studies affirm the advantages brought by online teaching, from a dialectical view, but also point out the shortcomings and problems in the practical process [29], and put forward suggestions or ideas for further online teaching optimization [3,12,27].

Regarding the methods, when searching for papers related to the topics of this article, it is found that many authors discussed or reflected on the process of college mathematics online teaching based on their identities as college mathematics teachers by action research [4,7,13]. Some studies used theoretical research methods to analyze the online teaching practice of mathematics in colleges and point out the advantages and problems [3,5,28-31,32]. Besides, there are also some empirical studies. For example, Zhao used the method of analysis of grey relationship to study the factors influencing online teaching [33]. Some people investigated the influence of mobile phones on college students' online learning by a questionnaire survey [34]. There was only an article used questionnaires to study the influencing factors of online mathematics teaching in colleges among all of the studies while the length of the article is very small [12].

3.1.2 Selection of Teaching Platforms and Modes

Since online mathematics teaching in colleges is to be carried out, it is necessary to select the network platforms as media between teachers and students, and the teaching modes will be different from the traditional model. According to the summary of previous research results, it is found that in the practice process of college mathematics online teaching, the selection and utilization of teaching platforms and modes are shown in **Table 1**.

Table 1. Statistics on platform and model selection of online mathematics teaching in colleges

Authors	Platforms	Modes and Methods
Ding W [4]	Chaoxing Platform	Autonomous learning before class - teaching and answering questions in class - consolidating feedback after class
Liang YF [5]	Chaoxing Learning Pass (Live)	Uploading learning materials before class - Live teaching in class - After-class exercise and feedback questionnaire
Zhao HN [6]	Chaoxing Learning Pass+DingTalk	Clearing learning objectives before class - integrating participatory activities in class - supervision and Q & A after class
Gu YQ. [7]	Online open course sharing platforms for colleges and universities in Zhejiang Province+DingTalk+CloudClass	the preparation of teachers' and students' - Heuristic Teaching (Live) -Consolidation after class (testing, homework, coaching)
Li GH [8]	Enterprise WeChat, Tencent Classroom, QQ Group Classroom, DingTalk, various MOOC platforms, and online learning platforms for colleges	
Qiao L [9]	Treenity, Screen Sharing, and WeChat Subscription	Releasing learning resources / Autonomous learning before class - Screen sharing (Live)

Authors	Platforms	Modes and Methods
Zhang HJ [10]	Chaoxing Platform	- Homework, Q & A, information feedback Blended learning & SPOC
Huang H [11]		Teachers choose resources/students' self-study Online - Problem-oriented teaching - Assessment and evaluation after class
Sun ZJ et al. [12]	MOOC, Rain Classroom, Cloud Class, Treenity, Chaoxing, and CNMOOC	Arranging tasks before class and carefully designing content - Q & A based classroom teaching - supervising students' consolidation after class
Zhang. X. Q. et al. [13]	Dayi Intelligence	Teachers' preparation before class, students' fragmented learning - Organizing teaching in class - Learning feedback after class
Zhang LD [14]	Treenity & Tencent Classroom	Blended Learning
Kang M [15]	SPOC	"Three-stage & four-step" flipped classroom teaching mode based on SPOC
Yan PS [16]	Chaoxing + QQ Groups	Students learn online courses - Interactive teaching in class - consolidation of homework after class
Li MQ [17]	Rain Classroom & Group Class	Finishing the learning tasks before class-Live teaching-Feedback after class
Liu QP et al. [18]	Tencent Classroom+MOOC+QQ Groups	Preparation before class - explanation in class - consolidation and feedback after class
Gao X et al. [19]	MOOC+Flipped Classroom	Teaching preparation and study preparation-Group cooperation and exchange-Homework and knowledge development
Zhou ZH [20]	MOOC practice based on SPOC	Including all aspects of teaching practice improvement before class, during class, after class, and learning evaluation
Yang XD [21]	QQ Groups, Wechat Groups, and MOOC	Students' independent learning & Teacher's instruction
Zhang Q et al. [22]		Pre-class preparation-Focus on the concepts and summary in class-Homework, test, and Q&A after class
Zhang Z [23]	Online teaching + MOOC platform assistance (Enterprise WeChat, QQ, Rain Classroom, DingTalk, Chaoxing, etc.)	Blended Teaching

The results in **Table 1.** are obtained from the previous papers and summarize the selection of online teaching platforms and models in teaching practice. From the previous research results, we can see that the network platforms for online teaching of mathematics in colleges under the background of epidemic situation mainly include QQ, Wechat, Chaoxing, Tencent classroom, DingTalk, rain classroom, MOOC, Treenity, Cloud Class, government education platforms, etc. Some teachers also use handwriting pads and *Windows Ink* in the teaching process to enhance the teaching effect [7]. For the teaching modes,

the current online teaching practice mostly adopts the blending teaching mode including students' self-study and online teaching, rather than blindly adopting the traditional model.

3.2 Strategies of Online Mathematics Teaching in Colleges

3.2.1 Preparation Before Class

For the preparation before class, Liang proposed that teachers should create a network course before class, prepare a series of learning materials for students, and let students learn

independently to form a curriculum cycle system of "teachers-online platform-students" [5]. Gu thought that mathematics teachers must accept the training of network teaching platform in advance before carrying out online teaching, choose the operation platforms suitable for them and students' learning conditions to store online learning resources, and then carefully design the whole teaching process [7]. Huang and others believed that teachers should make full use of the online teaching platform before class and push micro-class resources that are already available on the Internet or recorded by themselves to guide students to learn independently [9,11,13]. Zhang believed that teachers should release teaching syllabus, courseware, electronic teaching materials, and other forms of teaching resources in advance for students' autonomous learning, formulate teaching objectives seriously, decompose and refine teaching contents, and determine a reasonable weekly learning plan [13]. Peng put forward the preparation strategies before class from the perspectives of teachers and students. Teachers should make PPT carefully, help students clarify task points, and establish class groups to facilitate communication; at the same time, questionnaires must be issued to students to grasp their learning situation, and students must clarify the content of the preview, watch the teaching videos carefully keeping thinking, and complete the learning tasks and discover questions from them [35]. Li proposed to use Rain Classroom and Group Classroom to allow students to conduct online learning before class and discuss questions [17]. Han believed that teachers should initiate a link to the class QQ group 15 minutes in advance, and upload the learning materials to the students through the network platform one week in advance [24].

For the arrangement of homework before class, Zhang proposed to arrange homework in the form of group cooperation to test the effect of autonomous learning [14]; Kang proposed to arrange tests for students to collect and analyze the completion of test questions [15]. Regarding the classroom atmosphere and the state of teachers, Jia proposed that teachers should deal with the surrounding environment before class to create a classroom atmosphere, and be prepared to face students energetically, and avoid being lax.

3.2.2 Activities in Class

How to conduct effective interaction and communication with students in the classroom has become the top priority of teaching work.

Liang proposed that online interaction between teachers and students should be paid attention to in class, and students should be divided into groups for online discussion to realize the flipped online classroom [5]. Gu proposed that teachers should adopt the method of live network teaching. The teaching content is mainly to answer questions and consolidate the content of students' autonomous learning before class [7]. Qiao thought that the teacher's "teaching scripts" are indispensable, and the teacher's explanation and student's activities should be combined to improve students' concentration [9]. Zhang and others proposed that with the help of the "Dayi Intelligence", teachers and students can interact in the teacher-student dialogue area and other channels, and teachers can set assessment indicators through the system to record the learning process [13]. Kang proposed that teachers should show the completion of tasks in class, carry out problem inquiry activities, explain knowledge to students by classifying and summarizing points, and then release tests in the class [15]. Gao and others adopted a teaching model combining MOOC and flipped classrooms, taught knowledge in a targeted manner, and arranged two tests (homework and knowledge development exercises) before the end of the class [19]. Zhang believed that online teaching cannot control students' mastery in time, so we should control the teaching time within a certain time range according to the amount of teaching content, leaving time for students to discuss by themselves [22]. Zhang believed that the online and offline hybrid teaching mode and the method of webcast or "screen recording + online Q&A" should be adopted, and the calculations should be deduced and checked with the help of tablets, iPad, and other devices to restore the teaching scenes [23]. Feng believed that teachers should pay attention to the summary of knowledge points in the classroom teaching process, explain the problems in the homework before class, encourage students to ask questions, and build a teaching process led by questions and answers [26]. Jia thought that the purpose of curriculum design must be to improve students' participation and put forward a variety of measures to enhance students' interest and attention, such as using text, voice, video, and other ways to interact, selecting interactive topics that students are interested in, allowing students to discuss freely and record project videos [31]. Zhang and others thought that online mathematics teaching should pay attention to the application of various mathematical software [36], which is committed

to improving the effectiveness of distance teaching [37].

Besides, for the classroom atmosphere and discipline, Gu proposed that teachers should call the roll before teaching to master the attendance of students [7]. Huang and others proposed to let students sign-in on the network platform to maintain the order of the classroom [11,14]. Zhang proposed to use the functions of network teaching platforms such as roll call to supervise students' attendance [23].

3.2.3 Strategies after Class

Both online teaching and traditional teaching modes require a complete teaching process and evaluation system. Previous studies have also discussed the teaching strategies after class, mainly including homework correction and Q & A, feedback, and teaching evaluation. For homework correction and Q&A, Ding proposed to correct the students' homework in time, prepare text analysis, or record explanation videos according to the difficulty of the topic, so that students can consolidate the knowledge they have not mastered [4]. Zhang proposed to use the functions of "Q&A Discussion", "Homework Examination" and "Score Management" of *Treenity* to master students' learning situations and help them consolidate their knowledge [14]. Yang proposed to use the function of examination to conduct unit tests on students [21]. It is considered that the consolidation of students' knowledge should be realized through the layered complementation of online exercises and homework based on the development and construction of SPOC [20]. Ma proposed to set up comparative homework and conduct point-to-point tutoring, as well as a fixed time for answering questions for students to share their questions and ideas [38].

As for the feedback after class, Liang proposed to issue questionnaires to students to understand their knowledge consolidation and opinions of the teaching process [5]. Qv proposed that teachers should conduct surveys on students through questionnaires and voting to promote effective reflection and further improvement for teachers [25]. Han proposed to use QQ to answer questions online through text and voice [24].

As for teaching evaluation, Gao and others believed that both teachers and students should pay attention to self-summary and reflection to make adjustments in the direction of the next

teaching or learning [19]. Zhou proposed that teachers should combine online scores with final scores to establish a comprehensive evaluation system [20]. Feng believed that the evaluation of student performance should include offline assignments, unit tests, course discussions, and examinations [26]. Jia proposed that we should track the learning situation of students through the teaching platforms, convert them into quantitative indicators, and establish the ability evaluation system [31].

3.3 Reflections on the Practice of Online Mathematics Teaching in Colleges

3.3.1 Advantages of Online Mathematics Teaching in Colleges

Many studies have given affirmation to the practice mode of college mathematics online teaching and pointed out its advantages. Gu believed that online mathematics teaching makes teaching activities free of time and space constraints. Students can make use of abundant online resources to facilitate autonomous learning. Moreover, the forms of classroom interaction become diversified through online platforms, and the teaching statistics of platforms are also very detailed [7]. Zhang pointed out that advanced mathematics teaching under the Internet environment can arouse students' interest and increase enthusiasm. High-quality online teaching resources can help improve teaching quality. The most important thing is that this is an inevitable choice under the modern student-oriented education concept [36]. Chen and others believed that online teaching can describe abstract mathematical knowledge vividly through modern technology, and make teachers and students not limited by time and space [39].

3.3.2 Limitations of Online Mathematics Teaching in Colleges

Some of previous research on the online mathematics teaching mode not only point out the advantages, but also clarify the problems. Gu believed that long-term online learning will affect students' eyesight and reduce the communication efficiency between teachers and students. Moreover, it's difficult for teachers to control the process of class accurately. The congestion and paralysis of network platforms or signal are also unavoidable problems [7]. According to Li, because students' mathematical foundation are various, we cannot guarantee

every student can adapt to the online teaching activities well. Moreover, the teachers' adaptability to this mode greatly reduces the teaching efficiency, and there is also a lack of interaction and feedback between teachers and students [8]. So, they have poor self-control, which is difficult to resist the temptation to live outside of class [12]. Kong and others found that the enthusiasm of college students for learning has decreased significantly during the online teaching period, so schools need to pay more attention to the mobilization of students' enthusiasm and learning initiative to improve the quality of teaching [40].

3.3.3 The Influencers and Reform of Online Mathematics Teaching in Colleges

Since previous studies have recognized its limitations, some have discussed its causes, influencing factors, and reform suggestions. For the reasons why the online teaching effect is not ideal, Sun and others explored the influence degree of online mathematics teaching by issuing questionnaires to students. The results showed that the low efficiency of online teaching is mainly because of the poor self-control and initiative of students. At the same time, the problem of network speed is also an important reason why the teaching process stuck [12,16,21]. Taking the online teaching of mathematics in Higher Vocational Colleges as the object, Jia pointed out that the reasons for the poor effect of online teaching mainly include the reduction of teachers' subjective initiative caused by the ineffective supervision of the college and the lack of students' initiative and learning ability [31].

As for how to further optimize online teaching, Zhang believed that the urgent task is to speed up the construction of teaching platform and teachers to promote the reform of information technology and blended teaching mode [3]. Li proposed that teachers should teach following students' professional foundation to solve the problems in online teaching, accept online teaching training and network technology and optimize the teaching mode and evaluation system [8]. Sun and others proposed that it is necessary to design each teaching process and materials carefully to further optimize the teaching methods so that students can absorb new knowledge in the presentation and resolution of problems and also pay attention to students' consolidation and expansion after class [12]. Yan pointed out that it is difficult to carry out

online learning for students who have no conditions, insufficient learning ability [16]. Yang believed that teachers should learn all their lives, guide teaching activities with scientific and systematic methodology, strengthen the study and research of professional knowledge, and become scientific-research-oriented teachers who can reform teaching modes and optimize teaching design [21]. Zhang and others pointed out that in the online teaching of higher mathematics, we should pay attention to the innovation of teaching methods, the diversity of online teaching forms, strengthen the effective integration of online teaching and offline teaching to implement complementary advantages, and build a diversified evaluation system [36].

4. DISCUSSION

4.1 Summary of Previous Results

Combined with the analysis of the previous research, from the summary of the research objects, content and methods, we can see that the predecessors have studied the online teaching mode of advanced mathematics, linear algebra, probability theory and mathematical statistics, etc. Moreover, some have been carried out for general higher mathematics courses. Advanced mathematics has become the most studied course. The research content not only discussed the implementation strategies of many links such as before class, in class, and after class and evaluation, but (it) also involved the advantages, limitations, influencing factors and optimization suggestions of online teaching mode of mathematics in colleges. There are some implementation strategies before class, such as preparing and uploading teaching resources, clarifying teaching objectives and design, issuing learning task lists to students, and answering questions for teachers. Students should carry out offline autonomous learning and complete assignments and tasks based on the resources released by teachers, and pay attention to thinking and questioning in this process. The point of strategies in class is to realize the effective interaction between teachers and students. For example, teachers adopt heuristic methods and problem-based teaching mode, realize benign interaction with students through the function of network teaching platform, and arrange exercises tests, or homework to master the learning effect. Students should listen carefully and ask and answer questions actively in class. For after-class implementation strategies, teachers should promptly assign,

correct and supervise the completion of students' homework, arrange Q&A sessions, explain students' confusions patiently, and use some means to obtain classroom feedback and experience from students for further improvement. Finally, teachers must formulate a reasonable teaching evaluation system to achieve the purpose of evaluation. Students should complete their homework and give feedback to the teacher as required, consolidate, and review knowledge in time after class. As for the reflection on the online teaching of mathematics in colleges, previous research not only affirmed the advantages and teaching effectiveness of online teaching, but it also analyzed its shortcomings and limitations rationally compared with the traditional teaching mode, and put forward suggestions for optimizing the online teaching of mathematics. It can be seen that the previous research has made a lot of achievements, which has laid a good foundation for follow-up research.

4.2 Critical Reflection on Previous Research

There are some deficiencies in previous studies. For the research methods, first of all, some studies adopted the action research method. Teachers discussed teaching links After classifying and summarizing the practice. Besides, some used the theoretical research method to discuss the advantages, problems, and suggestions for optimization and improvement in the practice of mathematics online teaching. But in all the references, there is only one article including empirical research methods, and it only appeared as a part of the paper, which has not become a rigorous topic [12]. In the process of review, it is found that there is no article used data analysis to measure the implementation of mathematics online teaching. Therefore, there are some limitations in the selection of methods, and there is a lack of empirical research to strengthen the persuasion and reliability. As for the depth and breadth of research, secondly, although predecessors have obtained many results, the depth and breadth are very limited, it is still in the initial stage of development even online teaching based on the background of the new epidemic situation develops rapidly, and many problems need to be solved.

Also, there are still some gaps in previous studies. First of all, although previous studies have included online teaching research for

multiple courses such as advanced mathematics, linear algebra, probability theory and mathematical statistics, mathematics courses are not limited to these, so online teaching research for other courses is one of the blanks for future research. Secondly, given the great differences in the major categories and levels of students, the online teaching modes and strategies discussed by predecessors are not completely applicable to all majors and students at various levels. In previous studies, there is little discussion on the teaching mode of students at different levels and major categories, that is, the professionalism and pertinence of college mathematics online teaching are the directions for future research. Finally, some studies have shown that the learning effect of completely abandoning traditional teaching methods and using online teaching is unsatisfactory. The combination of online teaching and traditional mode is more suitable for students. Therefore, it is necessary to reform the teaching evaluation system suitable for online and offline. The teaching evaluation system of the blended teaching mode is imminent, and it is an important research breakthrough.

5. CONCLUSIONS

We drew the following conclusions through reviewing, combing, and analyzing the previous achievements on mathematics online teaching in colleges:

- (1) Domestic studies mainly focused on the selection of online teaching platforms and modes, the implementation strategies of college mathematics online teaching (before class, in class, and after class), and evaluation reflection (advantages, limitations, influencing factors, and optimization). Previous studies have included many achievements, reached a certain depth, and laid a good foundation for previous studies.
- (2) There are some deficiencies in previous studies. Secondly, although predecessors have made many achievements, their depth and breadth are very limited.
- (3) There is still a lot of research space in this subject, such as online teaching research for other mathematics courses, online teaching research for students of different professional categories and levels, the construction and improvement of teaching evaluation systems suitable for the blended teaching model.

Therefore, it is necessary to adopt more scientific methods to expand the research scope and room further and increase the research depth to make future research more in-depth and comprehensive.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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