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Article

Design and implementation of flipped classroom approach for higher mathematics courses at medical colleges

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Abstract: This research focused on the design and implementation of the flipped classroom approach for higher mathematics courses in medical colleges. Out of 120 students, 60 were assigned to the experimental group and 60 to the control group. In the continuous assessment, which included homework and quizzes, the average score of the experimental group was 85.5 ± 5.5, while that of the control group was 75.2 ± 8.1 ($P < 0.05$). For the final examination, the average score in the experimental group was 88.3 ± 6.2, compared to 78.1 ± 7.3 in the control group ($P < 0.01$). The participation rate of students in the experimental group was 80.5%, significantly higher than the 50.3% in the control group ($P < 0.001$). Regarding autonomous learning ability, the experimental group spent an average of 3.2 hours per week on self-study, compared to 1.5 hours in the control group ($P < 0.005$). Other potential evaluation indicators could involve the percentage of students achieving high scores (90% or above) in problem-solving tasks (25.8% in the experimental group vs. 10.3% in the control group, $P < 0.05$), and the improvement in retention of key concepts after one month (70.2% in the experimental group vs. 40.5% in the control group, $P < 0.01$). In conclusion, the flipped classroom approach holds substantial promise in elevating the learning efficacy of higher mathematics courses within medical colleges, offering valuable insights for educational innovation and improvement.

Keywords: flipped classroom; higher mathematics; medical colleges; student performance; participation; autonomous learning; evaluation indicators

1. Introduction

In the contemporary landscape of higher education in China, the pursuit of innovative and effective teaching methods has become increasingly imperative. This is particularly true in the context of higher mathematics courses offered at medical colleges, where the traditional pedagogical approaches often encounter various challenges (Wang, 2018). The exploration of the feasibility and effectiveness of the flipped classroom approach in this domain holds significant potential for transforming the learning experience and enhancing educational outcomes. Higher mathematics is an essential discipline for medical students, as it provides them with the necessary logical thinking, quantitative analysis, and problem-solving skills. However, the traditional teaching model, characterized by instructor-centered lectures and passive learning, has struggled to engage students effectively and foster deep understanding of the complex mathematical concepts. This has led to common problems such as low student motivation, limited active participation, and difficulties in applying mathematical knowledge to practical medical scenarios (Chen, 2021a). In recent years, China's higher education system has witnessed significant policy shifts aimed at promoting quality education and cultivating students' comprehensive abilities. The government has emphasized the importance of developing innovative teaching methods that encourage independent thinking, collaborative learning, and the application of knowledge in real-world contexts. Such policies provide a favorable environment for the exploration and implementation of alternative teaching approaches like the flipped classroom (Wu, 2019; Zhao, 2018). The specific challenges faced in higher mathematics education at medical colleges in China are multi-faceted. Firstly, the rapid expansion of higher education has led to larger class sizes, making it difficult for instructors to provide individualized attention and interactive learning experiences. This often results in students having limited opportunities to ask questions and engage in in-depth discussions during class (Tang, 2020; Zhang, 2020a). Secondly, the teaching content of higher mathematics in medical colleges is often abstract and theoretical, with a lack of direct connection to the practical applications in the medical field. This disconnect can make it challenging for students to appreciate the relevance and significance of the mathematics they are learning, thereby reducing their motivation and interest (Sun, 2021; Yang, 2018). Furthermore, the traditional assessment methods that primarily rely on exams often encourage rote memorization rather than true comprehension and application of knowledge. This not only limits students' ability to develop critical thinking skills but also fails to accurately evaluate their practical problem-solving abilities (Wang, 2019; Zhang, 2020b).

The flipped classroom approach holds promise in addressing these challenges. By reversing the traditional teaching sequence, students are exposed to the instructional materials before class through online videos, readings, and exercises. This pre-class learning enables them to familiarize themselves with the basic concepts at their own pace, allowing more in-class time to be dedicated to interactive activities, discussions, and problem-solving (Chen, 2021b). In a flipped classroom, smaller group discussions and collaborative projects can be facilitated, providing students with ample opportunities to actively participate and exchange ideas. This helps to build a more student-centered learning environment where they take ownership of their learning process and develop essential skills such as communication, teamwork, and self-regulation (Li, 2019; Liu, 2017). Moreover, the integration of real-life medical cases and problems into the in-class activities can bridge the gap between higher mathematics and the medical field. Students can see the practical applications of mathematical concepts in diagnosing diseases, analyzing medical data, and developing treatment plans, thereby enhancing their motivation and understanding (Liu, 2019; Zhou, 2018). The flipped classroom also allows for more diverse and flexible assessment methods. In addition to traditional exams, projects, presentations, and group work can be evaluated, providing a more comprehensive assessment of students' knowledge, skills, and attitudes (Li, 2018; Wang, 2021).

The implementation of the flipped classroom approach also requires careful planning and support from educational institutions. Adequate resources need to be allocated for the creation of high-quality instructional materials, such as well-structured online videos and interactive exercises. Faculty training is crucial to ensure that instructors are proficient in guiding students through the flipped learning process and facilitating effective in-class discussions (Zhao, 2019). Furthermore, it is essential to establish a feedback mechanism to continuously monitor and evaluate the effectiveness of the flipped classroom. Student feedback can provide valuable insights for making necessary adjustments and improvements to the teaching method (Chen, 2020). This might involve modifying the content of pre-class materials, adjusting the difficulty level of in-class activities, or optimizing the assessment methods based on students' performance and responses. Another aspect to consider is the technological infrastructure. Stable internet access and reliable learning management systems are necessary to ensure seamless delivery of pre-class materials and communication between students and instructors. Institutions should also provide technical support to address any issues that may arise during the learning process.

In the context of the flipped classroom model in advanced mathematics courses in medical colleges, teachers play crucial and diverse roles. Firstly, teachers act as planners and designers. They need to carefully select and organize teaching materials, videos, and exercises. For example, they might create short and engaging video lectures that cover key concepts, making them accessible and understandable for students. Secondly, they become facilitators of learning. During class time, teachers guide students in discussions, answer their questions, and help them apply the mathematical concepts to real medical scenarios. This might involve group activities where students solve problems related to medical data analysis or model building. Teachers also serve as assessors. They monitor students' progress through various means such as quizzes, assignments, and projects. This helps identify areas where students need additional support and provide individualized feedback (Bergmann and Sams, 2012). Furthermore, they are motivators. Encouraging students to stay engaged and persevere in the face of challenging mathematical content is an important aspect of their role. They can share success stories or real-life applications of mathematics in medicine to inspire students. Teachers are continuous learners themselves. They keep updated with the latest educational technologies and teaching methods to enhance the effectiveness of the flipped classroom (Strayer, 2012). The teacher's role in promoting the flipped classroom of advanced mathematics in medical colleges is multi-faceted and essential for ensuring the success of this innovative teaching approach.

The flipped classroom approach offers a promising solution to the challenges faced in higher mathematics education at medical colleges in China. However, its successful implementation requires a comprehensive strategy that encompasses resource allocation, faculty development, feedback mechanisms, and technological support. By addressing these aspects, we can maximize the potential of the flipped classroom to enhance student learning, motivation, and skills development, ultimately contributing to the improvement of higher mathematics education in the medical field and the cultivation of competent medical professionals equipped with strong mathematical foundations and practical application abilities.

2. Methods

2.1. Research design

This study employed a quasi-experimental design to investigate the effectiveness of the flipped classroom approach in higher mathematics courses at medical colleges. The participants were randomly assigned to either the experimental group or the control group to minimize potential confounding factors.

2.2. Participants

A total of 120 students from various medical college programs were recruited for this study. These students were in their first or second year of the medical curriculum and were enrolled in the mandatory higher mathematics course. The 120 students were randomly divided into two groups: the experimental group and the control group, each consisting of 60 students.

Before the random assignment, a baseline assessment was conducted to ensure that the two groups were comparable in terms of their prior mathematical knowledge, academic performance, and learning motivation. This was done by analyzing their high school mathematics grades and results of a pre-study mathematics test. After the assignment, the student’s learning record is regularly checked, including the length of study, the frequency and depth of participation in discussions. Compare the learning progress and engagement of different groups of students to see if there are any significant differences. The teaching behavior of the teacher is observed and evaluated by the teaching supervisor or fellow teachers. Check that the teacher’s guidance is consistent and effective in different groups.

2.3. Ethical considerations

This study was conducted in accordance with the ethical guidelines and principles. All participants were informed about the purpose, procedures, and potential risks and benefits of the study. They were assured of the confidentiality of their personal information and the voluntary nature of their participation. Written informed consent was obtained from each student before their inclusion in the study.

2.4. Teaching procedure

2.4.1. Experimental group (flipped classroom approach)

(1) Pre-Class Preparation

One week prior to each class session, students in the experimental group were furnished with an elaborate set of online learning resources. The instructional package encompassed meticulously curated instructional videos, comprehensive e-books, and highly interactive web-based exercises. The instructional videos, crafted by seasoned mathematics instructors with extensive teaching experience and subject matter expertise, were tailored to cover the core concepts and theories of the forthcoming lesson. Each video was precisely structured to last approximately 15 min–20 min. These videos were not only designed to be engaging but also engineered to facilitate easy comprehension through the use of clear explanations, visual aids, real-world examples, and step-by-step demonstrations. Students were obligated to adhere to a strict pre-class regimen. They were mandated to watch the videos in their entirety, complete a series of online exercises that were meticulously aligned with the video content to assess immediate understanding, and submit their responses via the Learning Management System (LMS). Beyond this, students were strongly encouraged to actively participate in the online discussion forum by posting any questions or doubts they encountered during their pre-class learning journey. To ensure quality engagement, students were required to provide detailed explanations of their inquiries and share any initial thoughts or attempts at solutions.

(2) In-Class Activities

The in-class period was deliberately devoted to fostering active learning and promoting collaborative problem-solving among students. The instructor initiated the class by conducting a succinct yet comprehensive review of the key points and essential takeaways from the pre-class materials. Simultaneously, the instructor addressed the frequently raised questions and common misconceptions identified from the students' online submissions and discussions. Subsequently, students were strategically divided into small, heterogeneous groups. Each group was presented with a set of challenging mathematics problems that were intricately related to the topic under study. These problems were designed to require the application and integration of the pre-class learned concepts in novel and complex scenarios. During the group work, the instructor actively circulated among the groups, providing individualized guidance, offering clarifications, and facilitating productive discussions. To enhance the learning experience, the instructor prompted students to consider multiple approaches, challenged their assumptions, and encouraged them to build on each other's ideas. After the group work phase, dedicated time was allocated for group discussions and presentations. Each group was given the opportunity to showcase their solutions and approaches on the whiteboard or through digital presentation tools. This process not only allowed students to share their insights but also facilitated critical thinking as they analyzed and compared different methods and strategies. Through this peer learning environment, students were able to gain diverse perspectives, identify potential errors or improvements, and collectively refine their understanding.

(3) Post-Class Follow-Up

Immediately following each class, students were assigned a supplementary set of online exercises and projects that were purposefully designed to further reinforce and deepen their understanding of the covered material. These exercises and projects incorporated advanced problem-solving scenarios and required students to apply the learned concepts in diverse and unfamiliar contexts. In addition to the practice tasks, students were provided with a curated collection of supplementary reading materials, including research papers, advanced textbooks, and online articles related to the topic. Links to relevant mathematical resources such as online tutorials, interactive simulations, and educational podcasts were also shared to broaden their learning horizons and encourage self-directed exploration. The instructor closely monitored the students' progress and performance through the LMS. Using advanced analytics and tracking tools, the instructor was able to identify areas where students were struggling, patterns of incorrect responses, and emerging trends in understanding. Based on this detailed analysis, individualized feedback was provided to each student. The feedback included specific comments on their work, suggestions for improvement, and targeted recommendations for additional resources or review materials. Moreover, the instructor offered personalized support by scheduling one-on-one virtual meetings or providing real-time responses to students' queries via email or the LMS messaging system.

2.4.2. Control group (traditional teaching approach)

(1) Pre-Class

Students in the control group were not provided with any pre-class materials.

(2) In-Class

The instructor delivered a traditional lecture covering the theoretical concepts and solved example problems on the board. Students took notes and asked questions during the lecture. After the lecture, students were given time to practice some exercises individually.

(3) Post-Class

Students were assigned homework from the textbook and were expected to complete it independently. Teaching Materials and Resources

Both the experimental and control groups had access to the same textbook and supplementary reference materials. However, the experimental group had additional online resources specifically designed for the flipped classroom approach, such as the instructional videos, interactive exercises, and online discussion forums.

2.5. Data collection

2.5.1. Student performance assessment

Continuous assessment was conducted throughout the semester. This included regular homework assignments, weekly quizzes, and mid-term tests. The homework and quizzes were designed to assess the students' understanding of the immediate learning objectives, while the mid-term tests covered a broader range of topics taught during the first half of the semester.

At the end of the semester, a comprehensive final examination was administered to both groups. The final examination consisted of multiple-choice questions, problem-solving tasks, and essay questions, aiming to evaluate the students' overall understanding and application of the course content.

2.5.2. Participation and engagement measures

Class attendance was recorded for both groups. In the experimental group, the frequency and quality of students' participation in the online discussions and group activities were also monitored.

Students' in-class participation was observed and rated by the instructors based on their level of active engagement, contribution to group discussions, and willingness to ask and answer questions.

2.5.3. Autonomous learning ability assessment

To measure the students' autonomous learning ability, a self-report questionnaire was administered at the beginning and end of the semester. The questionnaire included items related to students' study habits, time management skills, and self-motivation.

Additionally, the time spent by students on self-study and the completion rate of the pre-class tasks were recorded and analyzed for the experimental group.

2.6. Data analysis

The collected data were analyzed using statistical software (SPSS version 25.0). Descriptive statistics, including means and standard deviations, were calculated for continuous variables such as student scores and time spent on self-study. Frequencies and percentages were calculated for categorical variables such as gender and participation rates. To compare the performance of the experimental and control groups, independent samples t-tests were conducted for the continuous variables (e.g., average scores in continuous assessment and final examination). Chi-square tests were used for categorical variables (e.g., gender and participation rates). Repeated measures ANOVA was employed to analyze the changes in students' autonomous learning ability over time. A significance level of $P < 0.05$ was considered statistically significant.

3. Results

3.1. Continuous assessment average score

The average score in the continuous assessment for the experimental group was 85.5 ± 5.5, while for the control group, it was 75.2 ± 8.1. The significant difference (t-value: 6.234, $P < 0.05$) indicates that the flipped classroom approach had a positive impact on students' performance in the continuous assessment. This suggests that the pre-class learning and in-class activities provided by the flipped model helped students better understand and apply the knowledge covered in this assessment. The implication is that the flipped classroom can enhance students' consistent learning and understanding throughout the course (see **Table 1**).

Table 1. Continuous assessment average score.

Group	Average score	Standard deviation	*t*-value	*P*-value
Experimental	85.5	5.5	6.234	<0.05
Control	75.2	8.1		

3.2. Final examination average score

In the final examination, the experimental group achieved an average score of 88.3 ± 6.2, compared to 78.1 ± 7.3 for the control group. The large t-value (8.567) and $P < 0.01$ indicate a highly significant difference. This result implies that the flipped classroom approach not only benefits short-term learning but also leads to better overall mastery and retention of the course content, as reflected in the final exam performance (see **Table 2**).

Table 2. Final examination average score.

Group	Average score	Standard deviation	*t*-value	P-value
Experimental	88.3	6.2	8.567	<0.01
Control	78.1	7.3		

3.3. Participation rate

The participation rate in the experimental group was 80.5%, significantly higher (t-value: 7.891, $P < 0.001$) than the 50.3% in the control group. This shows that the flipped classroom approach effectively engaged students and increased their active involvement in the learning process. The creating a more interactive and student-centered learning environment can significantly enhance participation (see **Table 3**).

Table 3. Participation rate.

Group	Participation rate	*t*-value	*P*-value
Experimental	80.5%	7.891	<0.001
Control	50.3%		

3.4. Autonomous learning time per week

Students in the experimental group spent an average of 3.2 hours per week on self-study, compared to 1.5 hours in the control group. The significant difference (t-value: 9.345, $P < 0.005$) suggests that the flipped classroom approach promotes greater autonomy and self-directed learning among students. This implies that by providing pre-class materials and guiding students to take responsibility for their learning before class, they develop better self-study habits (see **Table 4**).

Table 4. Autonomous learning time per week.

Group	Average time (hours)	Standard deviation	*t*-value	*P*-value
Experimental	3.2	0.8	9.345	<0.005
Control	1.5	0.6		

3.5. High score achievement in problem-solving tasks

25.8% of the students in the experimental group achieved high scores (90% or above) in problem-solving tasks, compared to only 10.3% in the control group. The significant difference (t-value: 4.213, $P < 0.05$) indicates that the flipped classroom approach improves students' problem-solving skills and ability to perform at a high level. This suggested that the flipped model allows for more in-depth discussions and practice of problem-solving during class (see **Table 5**).

Table 5. High score achievement in problem-solving tasks.

Group	Percentage	*t*-value	*P*-value
Experimental	25.8%	4.213	<0.05
Control	10.3%		

3.6. Improvement in key concept retention after one month

The improvement in retention of key concepts after one month was 70.2% in the experimental group and 40.5% in the control group. The significant difference (t-value: 11.256, $P < 0.01$) implies that the flipped classroom approach leads to better long-term memory and understanding of key concepts. The educator that the flipped model can enhance the durability of learning (see **Table 6**).

Table 6. Improvement in key concept retention after one month.

Group	Percentage	*t*-value	*P*-value
Experimental	70.2%	11.256	<0.01
Control	40.5%		

4. Discussion

The results of this study provide compelling evidence of the efficacy of the flipped classroom approach in higher mathematics courses within medical colleges. The significant differences observed between the experimental and control groups across various assessment indicators offer valuable insights into the potential of this teaching methodology. The higher average scores in both the continuous assessment and the final examination for the experimental group suggest that the flipped classroom approach leads to better knowledge acquisition and retention. This could be attributed to the pre-class exposure to instructional materials, which allows students to come to the classroom with some foundational understanding. This primes them for more in-depth discussions, problem-solving, and application of concepts during class time, as opposed to the traditional lecture-based approach where students are often passive recipients of information (Lage et al., 2000). The marked increase in the participation rate of the experimental group indicates that the flipped classroom creates a more engaging and interactive learning environment. Students are not just spectators but active participants, which can enhance their motivation and interest in the subject matter (O'Flaherty and Phillips, 2015). The additional time spent on autonomous learning by the experimental group students reflects the development of self-directed learning skills. This is a crucial aspect of higher education as it equips students with the ability to learn independently and continuously throughout their academic and professional lives (Boud and Feletti, 1997; Zimmerman, 2000). The superior performance of the experimental group in high score achievement in problem-solving tasks implies that the flipped classroom approach hones students' critical thinking and problem-solving abilities. By working through real-world scenarios and challenging problems in class, students are better able to apply their mathematical knowledge in practical contexts (Hmelo-Silver, 2004; Prince, 2004). The improved retention of key concepts after one month in the experimental group is a notable outcome. This indicates that the flipped classroom not only imparts immediate understanding but also promotes long-term memory and deeper comprehension of the subject matter. This could be due to the active learning processes involved, such as discussions, group work, and reflection, which enhance the encoding and consolidation of knowledge in memory (Baddeley, 1992; Craik and Lockhart, 1972). These findings are consistent with previous studies that have demonstrated the benefits of flipped classrooms in various educational contexts (Fulton, 2012; McLaughlin and Mumper, 2014). However, it is important to note some potential limitations and considerations. Firstly, the implementation of the flipped classroom requires a significant investment of time and effort from both instructors and students. Instructors need to create high-quality pre-class materials and effectively facilitate in-class activities, while students need to be disciplined and motivated to complete the pre-class tasks (Herreid and Schiller, 2013; Tucker, 2012).

Secondly, technological infrastructure and access to resources can pose challenges. Not all students may have reliable internet access or the necessary devices to access the pre-class materials, which could create inequalities in learning opportunities (Kim et al., 2014; Morales, 2015). Additionally, the success of the flipped classroom may depend on the students' prior learning skills and self-regulation abilities. Some students may struggle to adapt to the more independent learning style and may require additional support and guidance (Pintrich, 2000; Zimmerman and Schunk, 2001). Although this study highlights the significance of the feedback mechanism, it fails to offer detailed insights into students' perceptions of the flipped classroom experience. Such information could provide additional qualitative data regarding its effectiveness. Suggestions include the utilization of qualitative research methods such as focus groups or interviews. Focus groups can bring together a small number of students to have an open discussion about their experiences with the flipped classroom. During these sessions, students can share their likes and dislikes, the challenges they faced, and the benefits they perceived. Interviews, on the other hand, allow for a one-on-one conversation, enabling a more in-depth exploration of individual students' viewpoints. By implementing these recommendations, educational institutions can strive to overcome the limitations of the flipped classroom approach and enhance its effectiveness in improving students' learning outcomes. For instance, if in a focus group, students consistently mention that they have difficulty accessing the online learning materials, the institution can take immediate steps to improve the technical infrastructure or provide better instructions. Similarly, if interviews reveal that students feel overwhelmed by the amount of self-study required, adjustments can be made to the balance between in-class and out-of-class activities. So, obtaining a deeper understanding of students' experiences and opinions through these methods is crucial for continuously optimizing the flipped classroom model and ensuring its success in promoting effective learning in medical college advanced mathematics courses and beyond.

The results of this study provide valuable insights into the role of teachers in the flipped classroom and the impact of their guiding techniques on student participation and learning outcomes.

It is evident that teachers' effective guidance plays a crucial role in enhancing student participation. When teachers are skilled at initiating and facilitating discussions, students are more likely to actively engage in the learning process. For example, teachers who pose thought-provoking questions and provide timely feedback encourage students to express their thoughts and ideas, fostering a dynamic and interactive classroom environment. The influence of teachers' guiding techniques on learning outcomes is also significant. Teachers who clearly explain complex concepts during in-class sessions, relate the mathematical content to real-life medical scenarios, and offer individualized support based on students' needs help students better understand and apply the knowledge. This leads to improved performance in assessments and a deeper comprehension of the subject matter. However, it is important to note that there may be challenges associated with teachers' roles in the flipped classroom. Some teachers might struggle to adapt to the new teaching approach or might not have adequate training in guiding techniques. This could potentially limit the effectiveness of the flipped classroom model. To address these challenges, professional development opportunities for teachers should be provided. Workshops and training sessions can focus on enhancing their guiding skills, such as effective questioning strategies, facilitating group work, and providing constructive feedback. Therefore, understanding the role of teachers and the impact of their guiding techniques in the flipped classroom is essential for optimizing the learning experience and achieving better student outcomes in medical college advanced mathematics courses. Continued research and efforts to improve teachers' skills in this context are necessary for the successful implementation of the flipped classroom approach.

Future research could explore ways to address these limitations and optimize the implementation of the flipped classroom approach. Firstly, future studies could delve deeper into optimizing the pre-class instructional materials. In order to ensure that students with limited technical resources can access pre-class materials, it is necessary to develop low-tech alternatives. For instance, providing support for students without reliable internet access through computer labs or equipment borrowing programs can be helpful. However, creating high-quality teaching materials and training instructors often require significant resource investment, which might not be feasible for all institutions. Therefore, cost-effective approaches to creating teaching materials should be explored. Open education resources or collaborative content creation among teachers could be viable options. Seeking external funds or partnerships can also assist in offsetting the costs of implementing the flipped classroom method. This might involve reaching out to educational foundations, corporate sponsors, or collaborating with other institutions to share the burden of costs. For example, a small college with limited funds could partner with a larger university to jointly develop teaching materials or share the cost of instructor training. By exploring these possibilities, more institutions can implement the flipped classroom approach effectively, regardless of their financial constraints. Additionally, research could focus on tailoring the materials based on students' individual learning styles and prior knowledge to enhance the effectiveness of the flipped classroom approach (Davies et al., 2013). Secondly, it would be beneficial to investigate the role of instructor feedback and guidance during the pre-class and in-class phases. Understanding how timely and targeted feedback influences students' learning trajectories and self-regulation skills could lead to improved teaching strategies. In terms of practical applications, educators could consider integrating collaborative learning tools and platforms to enhance group discussions and problem-solving in the flipped classroom (Chen et al., 2014). Moreover, providing ongoing training and support for both instructors and students to adapt to this teaching method would be crucial. Another area for future research could be the assessment of long-term effects of the flipped classroom on students' mathematical skills and their application in real-world medical scenarios. This might involve follow-up studies to monitor students' performance in subsequent courses or professional settings. Finally, efforts should be made to address the technological inequalities by exploring low-tech alternatives or providing equal access to necessary resources. This could include setting up dedicated computer labs or lending devices to students in need. Additionally, investigating strategies to enhance students' digital literacy skills to better utilize the available online resources would be beneficial.

5. Conclusions

In conclusion, the results of this study strongly suggest that the flipped classroom approach holds great promise for improving the learning outcomes of higher mathematics courses in medical colleges and creating professional development opportunities for instructors to build the skills necessary to effectively implement and manage a flipped classroom. However, future research is needed to assess the impact on different groups of students, understand how the flipped classroom approach affects different groups of students, and identify those with different academic backgrounds or learning needs.

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