

# Application of Flipped Classroom Teaching Mode Based on Rain Classroom App in Anesthesia Teaching

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## Research Article

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# Abstract

**Purpose** In the flipped classroom teaching of the key and difficult chapters, the purpose of this study is investigate whether the use of rain classroom software can achieve the maximum teaching benefits for more students.

**Methods** A total of one hundred and twenty-two third-year anesthesiology students from clinical medical college of Southwest Medical University were randomly divided into two groups, with 61 students in each group. One group was taught with flipped classroom teaching mode as the control group (FC group: flipped classroom group) and the other group was taught with flipped classroom software as the experimental group (FR group: flipped classroom + rain). The teaching content is the chapter of "acid base electrolyte balance and blood gas analysis". The teaching effect was evaluated by relevant theoretical tests, and the subjective feelings of students on the improvement of learning ability were evaluated by questionnaire survey.

**Results** Compared with FC group, the theoretical test scores of FR group were higher, and the subjective evaluation of multiple learning ability improvement in FR group was also higher. ( $P < 0.05$ ).

**Conclusions** In the flipped classroom teaching of key and difficult sections, using rain classroom software can make more students obtain greater teaching income than using flipped classroom teaching only.

## Introduction

In teaching, we should establish the teaching concept of "people-oriented and student-oriented", guide and promote students to participate in classroom learning, let students think independently, and let students express their ideas in an open way [1]. This is the application of cognitive psychology in teaching, which emphasizes the student-centered teaching concept. Flipped classroom teaching mode highlights the dominant position of students. In this teaching mode, teachers send learning materials to students before class, and students can flexibly self-study according to their own learning rhythm and acceptance ability; in class, they are committed to using knowledge for more active and in-depth learning by answering questions or discussion and analysis based on case situations [2].

Ausubel, a famous educational psychologist, thinks that meaningful learning is to connect new knowledge with original knowledge and bring new knowledge into learners' original cognitive structure. In the flipped classroom teaching mode, the teachers push the learning materials to the students for self-study before class, so that the students can establish a new knowledge system on the basis of the original knowledge, and build a new understanding of the existing knowledge through the exchange and discussion with teachers or other students in the classroom. According to Cunningham, an American cognitive psychologist, that is, "learning is a process of constructing internal psychological representation. Learners do not transfer knowledge from the outside world to memory, but build a new understanding based on the existing knowledge and experience through interaction with the outside

world." Cognitive psychology attaches importance to the inherent cognitive nature of human beings, including curiosity, cognitive needs, achievement motivation, etc. the respect for psychological cognitive laws in teaching design can mobilize students' cognitive drive, improve their cognitive structure and improve their cognitive methods [3]. Traditional teaching pays more attention to the teaching of knowledge structure and logical structure of teaching materials, but ignores the cognitive structure in students' minds [3]. Flipped classroom introduces the most popular lecturing mode in the classroom by using a series of modern teaching methods such as group discussion method, so as to guide and promote students to participate in classroom learning, and stimulate students' critical thinking and learning the deep thinking of materials can improve the ability of explanation, reasoning and application of new knowledge, and it will have a positive impact on students' learning attitude, learning habits and later learning methods [3]. In the classroom, we can build a new understanding of existing knowledge through the exchange and discussion with teachers or other students. This interactive teaching mode conforms to the cognitive structure of students [4].

In flipped classroom knowledge application, students can play a leading role in explaining the practical application of a certain knowledge point to the whole class. Learning from the book of rites, learning from each other, teaching is one of the most efficient learning methods, which is in line with the cone of learning proposed by Edgar Dale, an American scholar and famous learning expert Learning), because in the process of teaching to others, you will find your own lack of understanding of knowledge, and strive to overcome it, so that you can study knowledge more thoroughly and thoroughly, and finally learn more firmly. In order to enable students to master the knowledge of these important and difficult chapters, the teaching mode is introduced in the classroom discussion and knowledge application of flipped classroom, so that students can take the stage to explain to the whole class. However, due to the time limit of the class, only a small number of student representatives can take the stage to analyze and explain, which can not make all students stand on the platform to teach the application of knowledge points. In this teaching mode, most students can not get the best results in learning these important and difficult chapters, which is far less than those students who participate in the process of speaking on the stage, because Compared with the students who give lectures on stage, they lack enough enthusiasm, participation and opportunities for knowledge internalization. "Knowledge internalization" is the process that learners transform explicit knowledge into tacit knowledge, and it is a part of transforming new knowledge into learners' internal quality [5].

With the rapid development of "Internet", more and more front-line teachers integrate digital media, artificial intelligence, big data and other information technology into classroom teaching. With the popularization of multimedia hardware and the rapid development of educational information in colleges and universities, multimedia has increasingly become a necessary means in teaching. With the further development of flipped classroom, the demand for additional technical support is increasing. As a new teaching technology, rain classroom integrates PowerPoint and we-chat, providing technical support for every teaching link from pre class to after class [7]. One of the important components of effective teaching is students' participation, which plays an important role in students' learning [8]. Rain classroom is based on the teaching concept of taking students as the main body, so that every student can actively

participate in every learning link, which may better meet the needs of flipped classroom for technical support. Based on the flipped classroom teaching mode, we intend to explore the influence of rain classroom application on students' participation, enthusiasm and teaching effect..

## **Materials And Methods**

### **Study design and population inclusion**

One hundred and twenty-two third-year students majoring in anesthesiology in the Clinical Medical College of Southwest Medical University were randomly divided into two groups, 61 in each group. One group was taught with flipped classroom teaching mode as the control group (FC group: flipped classroom group) and the other group was taught with flipped classroom software as the experimental group (FR group: flipped classroom + rain). The experimental study was conducted with the help of a senior associate professor and a teaching assistant. The whole experimental design is based on the specifications of randomized controlled research and questionnaires are added. The specific flow of the study is shown in Figure 1.

### **Course arrangement**

The key and difficult content of "acid base electrolyte balance and blood gas analysis" is selected as the teaching content. A variety of novel learning activities in flipped classroom may cause students a feeling of uneasiness or loss, because they have not experienced these activities in the traditional classroom [9]. Therefore, the teaching staff will specifically introduce the classroom structure and teaching concept of flipped classroom to all students in advance, and explain to learners the principle of using flipped classroom in medical education environment may be useful At the same time, introduce the function and operation of rain classroom technology and its advantages to the students of FR group. In order to encourage teamwork in flipped classroom, students in each group are further divided into small teams with five students in each group.

Before class, the teacher prepared the teaching video of "six steps of blood gas analysis" course and put forward some related thinking questions. FC group sent the video to the student end through we-chat group online, and the FR group pushed the video to the student end through rain classroom software. After watching the video, each team discusses problems and prepares PowerPoint presentation for class presentation and discussion; in class, student representatives of each group give a 10 minute speech to review the knowledge points of the teaching video, and then put forward the unsolved problems of the group for class discussion. Each of the remaining groups publishes their answers to the questions and discusses the answers for about 20 minutes. For some particularly challenging problems, the students discuss and solve them together with the teaching assistant teachers. Finally, the teacher makes an authoritative summary (including an overview of the key points of theoretical knowledge of the course, the analysis of difficult problems encountered in the process of students' discussion, and encouraging

students to review relevant teaching materials after class), FC group is completed with the help of PowerPoint demonstration software, and FR group is completed with the help of rain classroom technology; after class, teachers assign homework, involving in the flipped classroom Students are required to complete and hand in their homework within three days. FC group completed this link with we chat and word documents, and FR group completed it through rain classroom technology. The teacher publishes the answers to the assignments online three days later and helps students solve challenging problems according to their requirements.

## Data collection

Before the course begins, all students are required to complete prediction questions about acid-base electrolyte balance and blood gas analysis. At the end of the course, both groups of students were required to fill in an anonymous questionnaire to evaluate their views on the teaching mode of their respective courses (including nine items, covering both positive and negative aspects). Finally, students' learning gains and interests in acid-base electrolyte balance and blood gas analysis were assessed by themselves. The three-point Likert scale (- 1, disagree, 0, neutral, 1, agree) was used to quantify students' views and self-assessment. The questionnaire is modified according to Paul Ramsden's curriculum experience questionnaire and Biggs' learning process questionnaire, and has been verified to be reliable and valid [10–11]. In addition, students need to report on the time spent in class preparation. In order to evaluate the students' learning of the course, a post test was conducted after the students completed all the courses. The test consists of multiple choice questions, multiple choice questions and discussion questions. We calculated the total score of each student for questions related to "acid-base electrolyte balance and blood gas analysis" and for questions related to "non-acid-base electrolyte balance and blood gas analysis". Independent sample t test was used to analyze the time spent in class preparation. Students' interest in the teaching content "acid base electrolyte balance and blood gas analysis" can be quantified as: 1. Not interested; 2. Somewhat interested; 3. Very interested.

## Statistical analysis

All statistical analyses were performed using SPSS 19.0 (IBM). All data were represented as mean  $\pm$  standard deviation (SD). Mann Whitney *U* test was used to compare the two groups [12–13], Cohen'd effect was calculated by psychometrica online effector calculator [14] and Cohen'd effect size is generally considered as: 0.0 – 0.1 = no effect; 0.2 – 0.4 = small impact; 0.5 – 0.7 = moderate effect; and 0.8 – 1.0 = significant effect [13].  $P < 0.05$  was considered as statistical significance.

## Results

A total of 122 students participated in the study, including 61 students in FC group and 61 students in FR group. The sex and age composition in the two groups were similar and no statistical significance, was shown in Table 1. The attendance rate in both groups was 100%. All students in both groups watched the

video course. The response rate of questionnaire and theory test in both groups was 100%. However, among the questionnaires received, some questionnaires scored "- 1" or "1" for all questions. For more objective analysis, these data were removed from the statistical analysis. A total of 119 reliable questionnaires were analyzed, including 59 from FC group (49.6%) and 60 from FR group (50.4%). In the theory test results of all the students, some objective questions all options are the same option, or subjective questions do not answer the test paper will be eliminated. A total of 117 reliable papers were analyzed, including 58 from FC group (49.6%) and 59 from FR group (50.4%).

Table 1  
Demographic information of medical students in both groups

	FC	FR	Statistics	DF	P value	
Number of students	61	61				
Gender	Male	29(47.5%)	26(42.6%)	$\chi^2 = 1.180^a$ (df=1)	1	0.277
	Female	32(52.5%)	35(57.4%)			
Age (years old)	21.13±1.13	21.07±1.08	t=0.328 (df=120)	120	0.694	
Note: $P < 0.05$ was considered as statistical significance.						

More students in the FR group believed that teaching staff could help them improve their learning motivation ( $P = 0.042$ ) and understand course materials ( $P = 0.027$ ), at the same time, the students in FR group were more satisfied with the teaching method of flipped classroom + rain classroom ( $P = 0.025$ ), as shown in Table 2. However, there was no significant difference between the two groups in "preparing for the examination". The students in FC group and FR group spent considerable time in class preparation ( $2.95 \pm 0.98$  hours vs.  $2.85 \pm 0.89$  hours,  $P = 0.562$ , effect dose = 0.105), as shown in Figure 2A.

Table 2  
Comparison of students' perspectives in both groups.

Items	Group	Disagree	Neutral	Agree	Statistics	P value	Effect size
The course improves my learning motivation.	FC	2(3.4%)	17(28.8%)	40(67.8%)	U=1485.0 (Z=-2.032)	0.042*	0.280
	FR	0(0.0%)	10(16.7%)	50(83.3%)			
The course is helpful for understanding the course material.	FC	3(5.1%)	24(40.7%)	32(54.2%)	U=1421.5 (Z=-2.207)	0.027*	0.345
	FR	1(1.7%)	15(25.0%)	44(73.3%)			
The course is helpful for the final examination.	FC	4(6.8%)	26(44.1%)	29(49.1%)	U=1505.0 (Z=-1.612)	0.107	0.260
	FR	2(3.3%)	20(33.3%)	38(63.3%)			
I am satisfied with the course.	FC	4(6.8%)	24(40.7%)	31(52.5%)	U=1411.5 (Z=-2.243)	0.025*	0.355
	FR	1(1.7%)	16(26.7%)	43(71.7%)			
I like this teaching method.	FC	4(6.8%)	23(39.0%)	32(54.2%)	U=1303.5 (Z=-3.023)	0.003**	0.467
	FR	1(1.7%)	11(18.3%)	48(80.0%)			
I would like this teaching method to be applied in the future medical curriculum.	FC	5(8.5%)	25(42.4%)	29(49.2%)	U=1440.0 (Z=-2.015)	0.044*	0.326
	FR	2(3.3%)	18(30.0%)	40(66.7%)			
This course gives me too much burden and pressure.	FC	15(25.4%)	29(49.2%)	15(25.4%)	U=1704.0 (Z=-0.390)	0.696	0.064
	FR	13(21.7%)	37(61.7%)	10(16.7%)			
This course occupies too much of my spare time.	FC	20(33.9%)	30(50.8%)	9(15.3%)	U=1622.5 (Z=-0.871)	0.384	0.144
	FR	23(38.3%)	32(53.3%)	5(8.3%)			
I need to spend a lot of energy on this course.	FC	22(37.3%)	27(45.8%)	10(16.9%)	U=1764.5 (Z=-0.032)	0.974	0.005
	FR						

Note:  $P < 0.05$  was considered as statistical significance.

Items	Group	Disagree	Neutral	Agree	Statistics	P value	Effect size
	FR	19(31.7%)	35(58.3%)	6(10.0%)			
Note: $P < 0.05$ was considered as statistical significance.							

More students in FR group thought that teaching staff could improve their clinical thinking ( $P = 0.005$ ), promote knowledge acquisition ( $P = 0.018$ ) and self-opinion expression ( $P = 0.040$ ). However, there was no difference in the two groups in terms of "communication skills" and "scientific thinking", was shown in Table 3. In addition, 95% of the students in the FR group said that they were "somewhat interested" or "very interested" in the acid-base electrolyte balance and blood gas analysis, which was higher than that in the FC group (81.36%), was shown in Figure 2B. The difference of overall interest score in the two groups was statistically significant ( $P = 0.031$ ,  $u = 1405.5$  ( $z = -2.153$ ), effect size = 0.361), and the FR group was higher than the FC group, was shown in Figure 2C.

Table 3  
Comparison of students' self-perceived competence in both groups

Items	Group	Disagree	Neutral	Agree	Statistics	P value	Effect size
The course improves my communication ability.	FC	1(1.7%)	24(40.7%)	34(57.6%)	U=1492.5 (Z=-1.789)	0.074	0.273
	FR	3(5.0%)	12(20.0%)	45(75.0%)			
The course improves my clinical thinking ability.	FC	5(8.5%)	18(30.5%)	36(61.0%)	U=1361.5 (Z=-2.778)	0.005**	0.406
	FR	1(1.7%)	9(15.0%)	50(83.3%)			
The course improves my ability to acquire knowledge.	FC	2(3.4%)	20(33.9%)	37(62.7%)	U=1423.5 (Z=-2.368)	0.018*	0.343
	FR	0(0.0%)	11(18.3%)	49(81.7%)			
The course improves my ability to give presentations and express my opinions.	FC	4(6.8%)	25(42.4%)	30(50.8%)	U=1437.0 (Z=-2.057)	0.040*	0.329
	FR	1(1.7%)	18(30.0%)	41(68.3%)			
The course improves my ability in scientific thinking.	FC	3(5.1%)	29(49.2%)	27(45.8%)	U=1526.0 (Z=-1.478)	0.139	0.239
	FR	1(1.7%)	24(40.0%)	35(58.3%)			

Note:  $P < 0.05$  was considered as statistical significance.

In addition, there was no significant difference in the scores of pre-test ( $74.80 \pm 11.23$  vs.  $75.61 \pm 10.47$ ,  $P = 0.684$ , effect amount = 0.074), was shown in Figure 2D.

## Discussion

In the flipped classroom teaching mode, it is not necessary to flip all the contents [9], but only partially flip the key and difficult knowledge of the teaching content. For example, acid-base electrolyte balance and blood gas analysis, the key and difficult parts in medical teaching, can not only reduce the learning burden of students before class, but also enable students to concentrate on the key and difficult knowledge points for targeted learning and exploration. There is evidence that students also prefer to

divide the curriculum into traditional classroom and flipped classroom [9]. In a study on engineering major, students pointed out that 30% of the flipped classroom and 70% of the traditional classroom are the best composition proportion [15]. In the teaching process, it is difficult for students to master the key and difficult knowledge points in each chapter efficiently, and some difficult points even perplex students and weaken their learning enthusiasm. Therefore, this study will focus on the key and difficult knowledge plate as the teaching content of the study, to explore the application of flipped classroom teaching mode based on rain classroom technology in the teaching of key and difficult content.

Compared with FC group, the students in fr group performed better ( $75.40 \pm 11.82$  vs.  $80.07 \pm 9.46$ ,  $P = 0.020$ , effect dose = 0.437). It should be noted that, Compared with FC group, the students in fr group performed better ( $75.40 \pm 11.82$  vs.  $80.07 \pm 9.46$ ,  $P = 0.020$ , effect dose = 0.437). It should be noted that, as shown in the pre-test, the acid-base electrolyte balance was comparable to the theoretical knowledge baseline of blood gas analysis in both groups before the study. These results are particularly encouraging to encourage educators to consider using rain classroom technology, as we have shown that it is very effective in helping students master and apply knowledge of acid-base electrolyte balance and blood gas analysis. From the perspective of "knowledge internalization", this paper analyzes and discusses the influence of flipped classroom teaching mode and rain classroom technology on teaching effect. Students watch the teaching video before class and solve the related problems raised by the teacher before class, so as to have the students' first knowledge internalization; in the classroom link, according to the feedback of students' watching the video before class, the teacher discusses and interacts with students in class to solve the problems that students don't understand The second knowledge internalization occurred, and students' knowledge internalization plays an important role in flipped classroom teaching effect [16–17]. The internalization of a concept, especially the internalization of complex and ill structured knowledge concepts that cannot be established spontaneously, is far from enough only through one internalization, and it can be mastered skillfully only after multiple internalization [18].as shown in the pre-test, the acid-base electrolyte balance was comparable to the theoretical knowledge baseline of blood gas analysis in both groups before the study. These results are particularly encouraging to encourage educators to consider using rain classroom technology, as we have shown that it is very effective in helping students master and apply knowledge of acid-base electrolyte balance and blood gas analysis. From the perspective of "knowledge internalization", this paper analyzes and discusses the influence of flipped classroom teaching mode and rain classroom technology on teaching effect. Students watch the teaching video before class and solve the related problems raised by the teacher before class, so as to have the students' first knowledge internalization; in the classroom link, according to the feedback of students' watching the video before class, the teacher discusses and interacts with students in class to solve the problems that students don't understand The second knowledge internalization occurred, and students' knowledge internalization plays an important role in flipped classroom teaching effect [16–17]. The internalization of a concept, especially the internalization of complex and ill structured knowledge concepts that cannot be established spontaneously, is far from enough only through one internalization, and it can be mastered skillfully only after multiple internalization [18].

Compared with the FR group, the FC group had lower high scores. Many of the students who got high scores were students who actively participated in the teaching. In the flipped classroom, only some students participate in the classroom speech, which improves the enthusiasm and participation of these students, and facilitates them to internalize their knowledge better. However, most of the students who did not participate in the speech lacked enough enthusiasm and opportunities for knowledge internalization. If these students who are not active enough to complete the task of self-study before class are not up to standard, lack of enthusiasm for interaction with teachers and students in class, and do not participate in the designated pre class or classroom activities, flipped classroom will not be able to support effective learning [19–20]. Rain classroom scientifically covers every teaching link from before class to after class, providing complete and three-dimensional data and technical support for teachers and students [7]. The application of rain classroom technology in flipped classroom teaching mode can help to form a new knowledge structure and improve students' learning efficiency by decomposing the difficulty of knowledge internalization and increasing the times of students' internalization. Compared with FC group, the use of rain classroom technology promoted the internalization of students' knowledge and improved the theoretical test scores of FR group. At the same time, the subjective evaluation of FR group on the improvement of learning ability was also higher. It highlights the advantages of rain Classroom: firstly, to improve students' interest in learning, enthusiasm and active learning ability, secondly, it helps to achieve personalized autonomous learning, thirdly, it helps to build a "relaxed and pleasant" classroom atmosphere.

Using rain class, teachers can push the preview materials with exercises, voice and MOOC video to students' mobile phones for self-study. Students' pre class learning situation can be fed back to the teacher, which plays a certain role in supervising and urging students' pre class self-study. At the same time, teachers can teach students according to their aptitude according to their learning conditions. In class, the functions of random roll call, real-time answer, bullet screen contribution, exercise push and red packet in class can realize the efficient interaction between teachers and students, which greatly improves the participation of all students. Enthusiasm provides a perfect solution for the interaction between teachers and students in classroom teaching:  real time answer in class, teachers can push exercises to the whole class in real time. On the one hand, it can improve students' concentration in class, and at the same time, it can also test students' mastery of knowledge points. The teacher can also cast all the students' answers on the screen for the whole class to browse. Students can compare their answers in the class to reflect on their own learning deficiencies.  Bullet screen interaction and contribution: the teacher can select any time point to open the barrage function, all students can speak freely and actively express their personal opinions. The bullet screen content sent by students will be displayed on the large screen of lectures, and both teachers and students can browse. Therefore, the bullet screen function provides most students who have not been on stage to express their opinions and opinions to the whole class Space and opportunity. If you are worried that the opening of the barrage will affect the students' concentration in class, the teacher can turn off the function of the barrage in class and open it between classes, so that students can also activate their thinking during the break time. Students can also send their opinions or questions to the teacher in the form of contribution, and the

content will not be directly displayed on the large screen. After receiving the contribution, the teacher can decide whether to put it on the lecture screen. ☒ Exercise push: teacher can push time limited (or unlimited) exercises to students at any time point before class, class and after class, as an evaluation test of students' learning situation. Students submit answers after answering questions, and teachers can check students' answers on the teacher's side and make corrections. ☒ Classroom red packets: teacher can reward students with excellent performance in class by giving them red envelopes. While activating the classroom atmosphere, they can fully attract and mobilize the attention of students and put them into classroom learning. After class, the rain classroom will send personalized reports of classroom teaching to teachers. Teachers can refer to the classroom reports to further understand the students' learning situation and make targeted suggestions students to solve doubts, find out the missing.

Flipped classroom is a deeper and more open teaching mode, and it may need to update the evaluation system to better evaluate the effectiveness of flipped classroom [21]. The results showed that there was no significant difference between FC group and FR group ( $62.74 \pm 10.41$  vs.  $65.81 \pm 8.67$ ,  $P = 0.085$ , effect amount = 0.321) (Figure 2(f)). When more complex evaluation indicators are included, for example, there are not only standardized multiple-choice questions, but also open subjective discussion questions; the evaluation level is not only the mastery of theoretical knowledge, but also includes learning ability, critical and creative thinking, students' reactions and opinions. The results are shown in Figure 2 (e). The final conclusion is that the teaching effect of the experimental group is better than that of the control group and the teaching effect of flipped classroom can be significantly improved with the help of rain classroom technology. Students have changed from traditional passive acceptance learning to active autonomous learning, and the evaluation depth and representativeness of standardized multiple-choice questions are insufficient, such as the improvement of students' learning ability, especially the cognitive ability of higher-order thinking, the improvement of problem-solving ability, inquiry ability and critical creative thinking [22]. This may be the main reason why some studies [23–24] have concluded that flipped classroom has little or no improvement in teaching income compared with traditional classroom.

This study also has some limitations. First of all, the teaching content of this study is the key and difficult knowledge in medical education. Due to the particularity and complexity of medical education [25], when it is extended to other teaching fields, the teaching mode of flipped classroom + rain classroom may not achieve good results. It is expected that more research will make up for this blank in the future. Secondly, the scoring standard of argumentative questions in the after-school theoretical evaluation is to score according to the key points. The reviewers may attach their own subjective judgment when marking, which may lead to certain scoring errors. However, all our papers are graded by the same reviewer, so as to avoid different scoring standards of different people, and strictly follow each score point, specific to each score detail, and reduce the error to the lowest.

To sum up, in the flipped classroom teaching of the key and difficult chapters of the teaching content, by using rain classroom software, compared with the simple use of flipped classroom teaching, more students can obtain greater teaching benefits.

## Declarations

Ethics approval and consent to participate: This experiment has been approved by the Ethics Review Committee of Southwest Medical University, all methods were carried out in accordance with relevant guidelines and regulations, and all participants in the experiment have signed

informed consent

Consent for publication: Not applicable.

Availability of data and materials: All data generated or analysed during this study are included in this article and the Figshare database([https://figshare.com/articles/dataset/Raw\\_data\\_xlsx/17429909](https://figshare.com/articles/dataset/Raw_data_xlsx/17429909)).

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# Figures

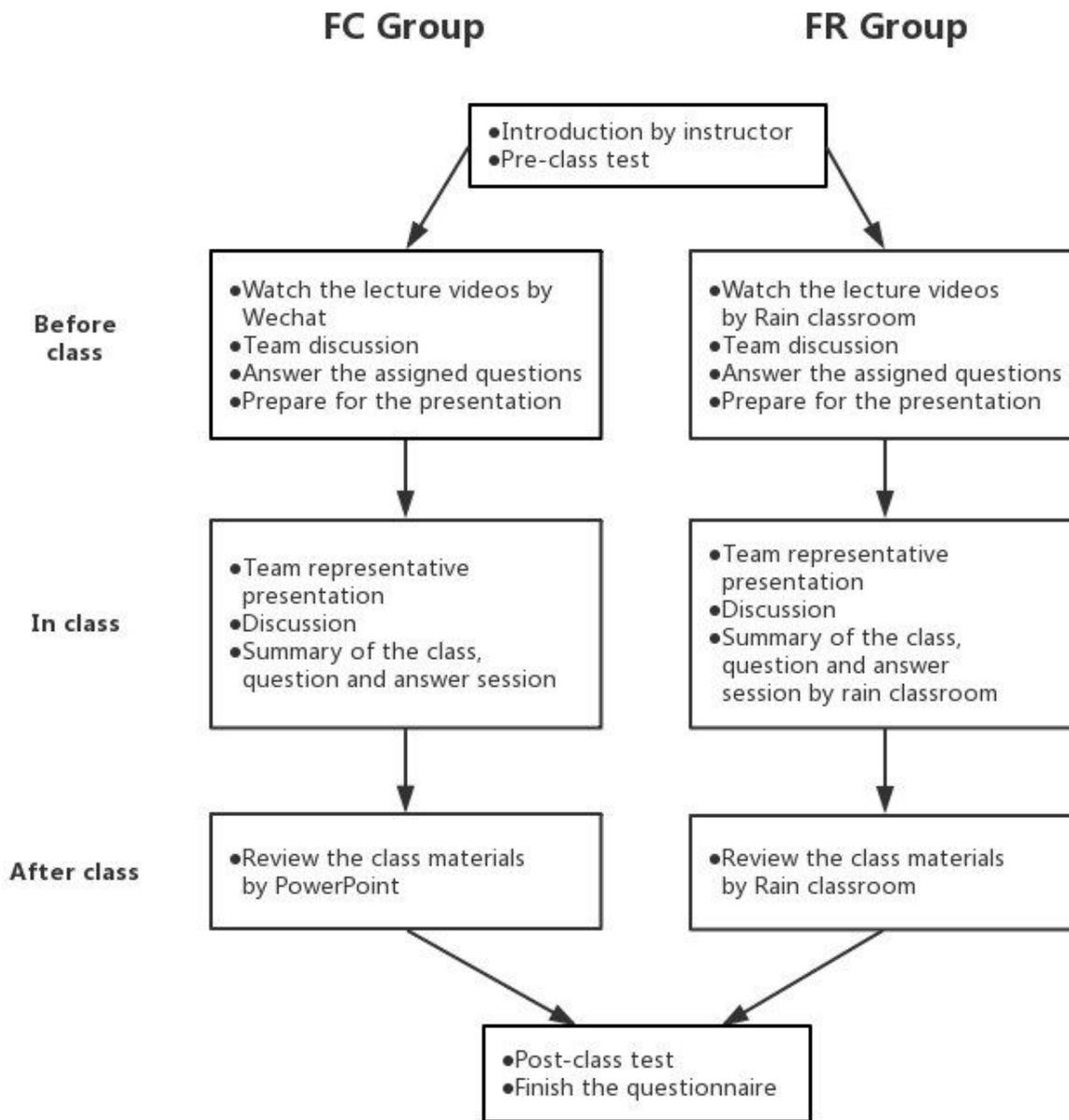
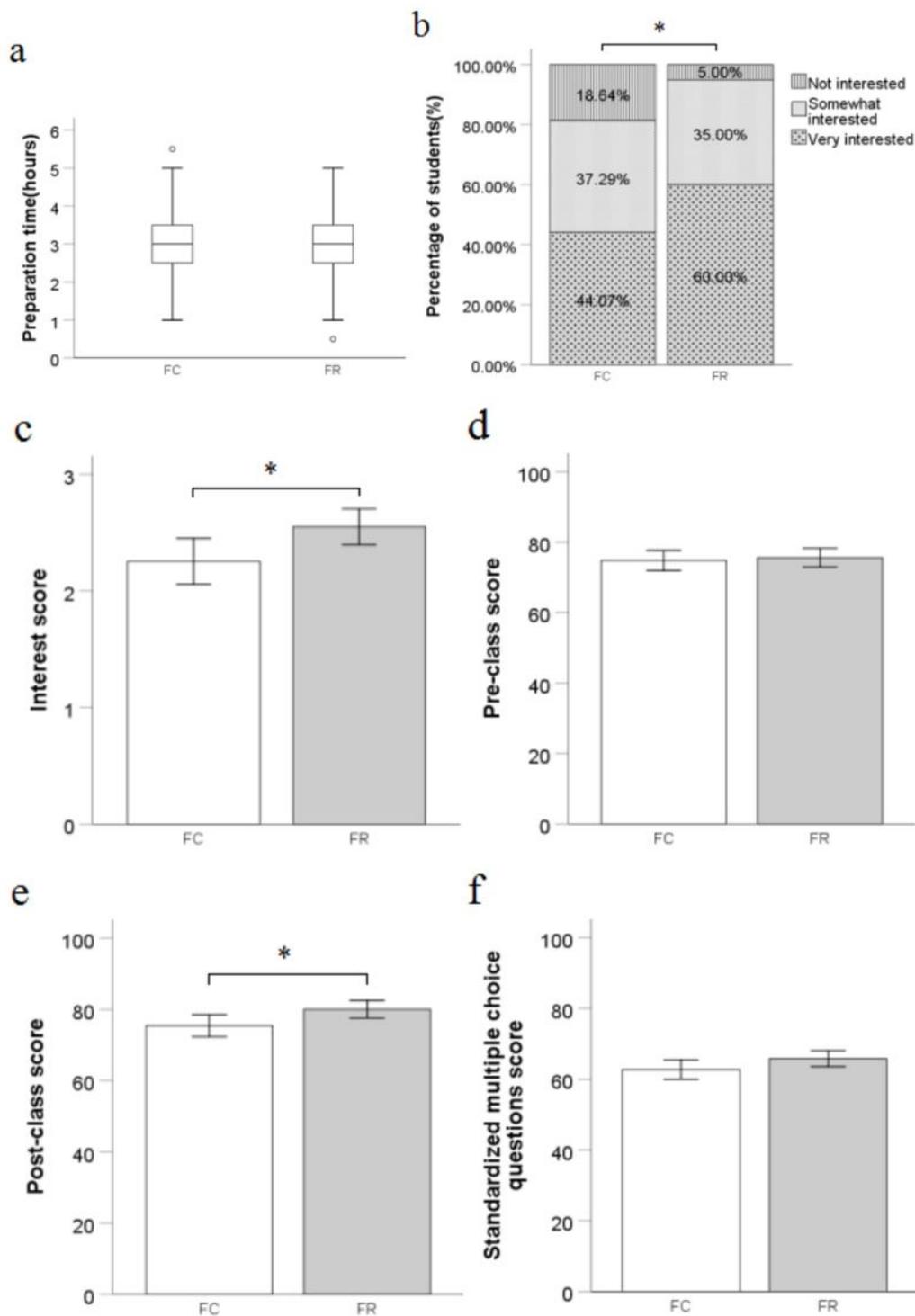


Figure 1

Flow diagram illustrating the flipped classroom and the flipped classroom+rain classroom model. FC: flipped classroom group, FR: flipped classroom+rain classroom group.



**Figure 2**

Feedback from students taking the flipped classroom compared to those taking the flipped classroom+rain classroom. (a) Box plot indicating the preparation time for the class between the two groups (hours). (b) Stacked column charts indicating the percentage of students interested in teaching material after taking the flipped classroom and the flipped classroom+rain classroom, respectively. \*P =0.031. (c) The level of students' interest in teaching material was quantified as follows: 1, not interested;

2, somewhat interested; 3, very interested. A Mann-Whitney U test was performed to compare the differences between the two groups. \*P =0.031. (d) Comparison of students' test scores before the classroom. (e and f) Comparison of students' test scores after the classroom. FC: flipped classroom group, FR: flipped classroom+rain classroom group.