ORIGINAL RESEARCH

Flipped Classroom Approach Used in the Training of Mass Casualty Triage for Medical Undergraduate Students

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ABSTRACT

Objective: The aim of this study was to explore the application of the flipped classroom approach in the training of Mass Casualty Triage (MCT) to medical undergraduate students.

Methods: In this study, 103 fourth-year medical students were randomly divided into a Flipped Classroom (FC) group (n = 51) and a Traditional Lecture-based Classroom (TLC) group (n = 52). A post-class quiz, simulated field triage (SFT) and feedback questionnaires were performed to assess both groups of students for their learning of the course.

Results: In the post-quiz, the median (IQR) scores achieved by students from the FC and TLC groups were 42(5) and 39(5.5), respectively. Significant differences were found between the two groups. In the SFT, overall triage accuracy was 67.06% for FC, and 64.23% for TLC students. Over-triage and under-triage errors occurred in 18.43% and 14.50% of the FC group, respectively. The TLC group had a similar pattern of 20.77% over-triage and 15.0% under-triage errors. No significant differences were found regarding overall triage accuracy or triage errors between the two groups.

Conclusions: The FC approach could enhance course grades reflected in the post-quiz and improve students' satisfaction with the class. However, there was no significant difference of competency between the two groups demonstrated in the SFT exercise.

Key Words: flipped classroom, traditional lecture-based classroom, training, mass casualty triage, medical undergraduate student

The Flipped Classroom (FC), also known as the reverse, inverse, or backwards classroom, is a blended learning approach in which lecture materials are consumed as homework, while active learning activities such as simulation, case-based discussion, or problem solving are used in the classroom.[1,2] In the past decade, the FC approach has shown benefits to knowledge acquisition, and gained global popularity in medical undergraduate education.[3-5] However, the overall effectiveness of the FC approach is also being questioned by some educators, as it didn't show any superiority while compared to the traditional lecture-based classroom (TLC) approach in some subjects.[6-8] Moreover, the pre-class workload, students' compliance, time spent outside of class, evaluation methods, and transfer of knowledge to professional practice and patient care in the FC are still under exploration.[7,9-11]

Mass Casualty Triage (MCT) is a core component of disaster medicine, which requires students to have a comprehensive grasp of knowledge of disaster management paradigms and triage algorithms. Additionally, according to a large questionnaire survey that was conducted among university students in southern China, rescue skills were the most critical knowledge area they thought necessary for disaster preparedness.[12] We therefore chose the MCT from a disaster medicine course as our teaching subject in this study. We intended to explore the application of the FC approach in this subject by comparing the differences in knowledge gain and retention, and by observing the level of performance of Simulated Field Triage (SFT) using the FC *versus* TLC module approaches.

MATERIALS AND METHODS

Participants and Study Design

This was a randomized and single blind study which was conducted from between May and June, 2019. MCT was a required class for fourth-year undergraduate students majoring in clinical medicine, and all the 113 fourth-year undergraduate students were enrolled. These students had passed the same national college entrance examinations, and obtained comparable scores. Before this study, they had the same lesson plans and had attended the same courses, according to the master syllabus and were taught by the same group of

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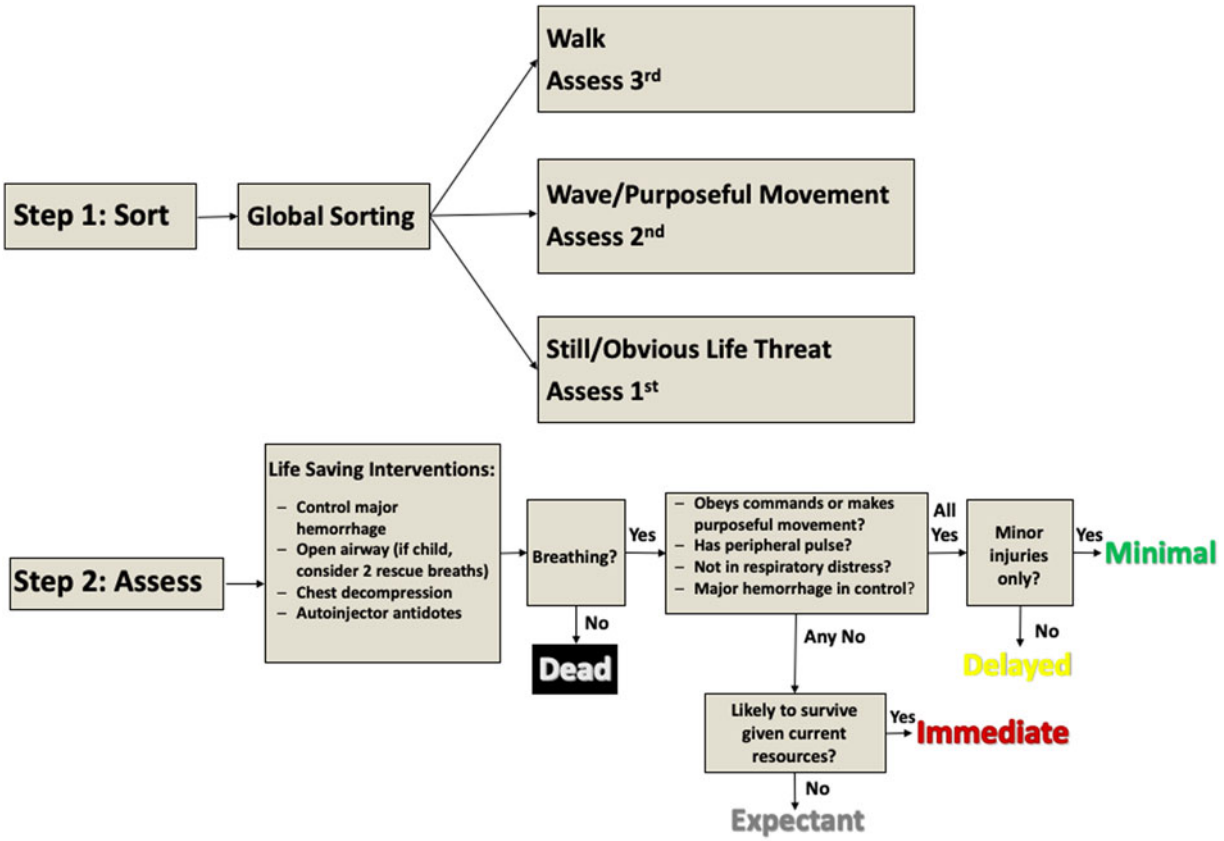
FIGURE 1

SALT Triage Algorithm.



teachers during their tenure at university. This study was approved by the Institutional Review Board of Sun Yat-sen University (IRB-SYSU), China. Every student had the right to refuse participation in the random grouping and completion of the study. The data of these students were excluded from our statistical analysis. A final total of 103 students agreed to attend this study, and all gave written informed consent. Grade point average (GPA) of these participants before this study was calculated. After a brief written test emphasizing clinical medicine as well as disaster medicine, we randomly divided these participants into either the FC or the TLC group by using a completely random design method performed by SPSS 22.0 version (IBM Corp, Armonk, NY). Both groups were supervised by a teaching group composed of one instructor and three teaching assistants, who worked in the Department of Emergency Medicine, First Affiliated Hospital, SYSU.

Teaching Subjects

Triage systems are utilized in Mass Casualty Incidents (MCIs) or disasters, to ensure that the most good is achieved for the largest possible number of victims in a resource-constrained environment.[13] There are many types of triage systems in use around the world. Among them, the Sort, Assess, Life-saving intervention, Treatment/Transport (SALT) triage system (Figure 1), which has been proposed as a national standard based on the best available science and expert consensus, has gained popularity for its reliability and simplicity in performing field, first pass, MCT.[14-17] Therefore, the SALT methodology is the most important triage tool that students must master in the MCT class.

Course Design

The graphic overview of the course design was shown in Figure 2. Both the FC and TLC groups covered the same teaching contents: SALT triage tool including its background, triage algorithm, and MCI cases based on triage-learning exercises.

Pre-Class Study

One week prior to the TLC, the students that were assigned to this group were asked to prepare for the class, relying only on the course textbooks. The students assigned to the TLC group were required to finish the pre-class exercises comprising

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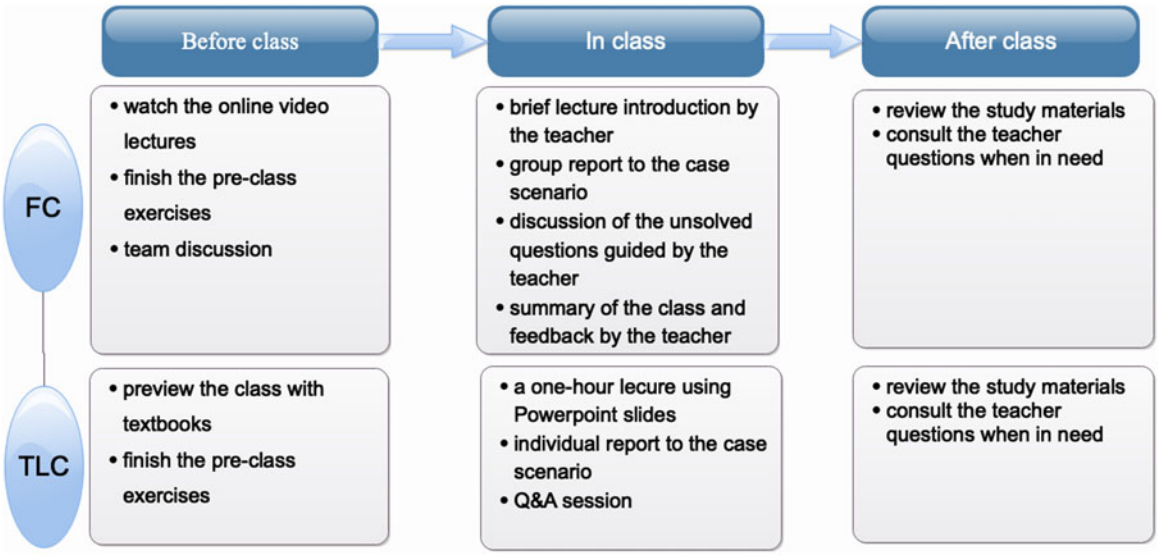
FIGURE 2

Flow Diagrams Illustrating the Teaching Methods of Flipped Classroom and Traditional Lecture-Based Classroom.



Abbreviations: FC, flipped classroom; TLC, traditional lecture-based classroom.

47 multiple-choice questions and 3 open-response questions chosen from the validated question bank developed by the Undergraduate Education Committee of SYSU. The open-ended questions were as follows: (1) What is the purpose of, and what are the guiding principles of, MCT? (2) What is the difference between in-hospital medical care and pre-hospital medical care? (3) How does one deal with casualties during an MCI, as medical resources change?

The design of the FC approach was inspired by an ophthalmology course conducted in SYSU[11] that was supervised by three educators. In this FC group, we also had three educators who successfully completed instructor courses in National Disaster Life Support (NDLS) training, and acquired training certificates. They were all emergency medicine physicians who were familiar with SALT triage. They were responsible for the production of pre-class online video lectures, which were made from the same course textbooks used by students assigned to the TLC group. In order to ensure that every student assigned to the FC group could maintain focus for the duration of the lecture,[18] each video lecture was made no longer than 30 minutes. There were 3 videos in total, with a recorded time of 25-30 minutes for each one. These digital learning resources were made available to the students a week prior to the class, and were accessible on all types of electronic devices, including mobile phones. The classroom didactic lecture was therefore replaced by pre-class video watching. Students assigned to the FC group could arrange the learning progress by themselves, and were also required to complete the same pre-class exercises as the TLC group.

In order to enhance their team's collaborative ability, students were encouraged to form 10 small groups, with 5-6 students per group, to discuss any problems they had encountered in the pre-class study and exercises.

In-Class Activities

Both the FC and TLC groups had the same in-class learning time of 2.5 hours. The in-class learning activities for the FC group began with a brief introduction of the subject and class agenda by the instructor for 10 minutes. This was followed by a case study that featured a scenario of a serious traffic accident causing 10 casualties.

After the presentation, three relevant questions were presented by the instructor as follows: (1) How does one ensure scene security? (2) How does one conduct effective communication with team members and the emergency center? (3) Which patient would be the first to be transported?

Students were asked to triage the casualties by using the SALT triage algorithm, and discuss any questions within their groups. During this period, the instructor and teaching assistants also actively rotated among the groups to guide the discussion, and provide explanations whenever necessary. Their roles were to guide students toward finding answers by themselves, and to inspire their enthusiasm for information exploration. Subsequently, one student from each group was randomly

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assigned to represent their team, give a ten-minute report on their triage choices, and answer any questions. The student also presented any unresolved pre-class questions from the team for in-class discussion.

At the end of the class, the instructor gave an over-all summary to the class, and provided additional feedback as needed. The in-class activities for the TLC group started with a one-and-a-half-hour didactic lecture, followed by a one-hour educational case study. The instructor presented the same case of a serious traffic accident and posed questions as in the previous group. After presentation of the case scenario, the students worked independently on triage choices and answered the questions that were asked as part of the exercise.

At that point several students were assigned to give their answers in the class. At the end of the class, the instructor gave detailed explanations for the correct answers and feedback to the students.

After Class Work

After class, students in both groups were encouraged to review the study materials and discuss questions with the teacher if needed. Students in the TLC group also had the same access to the video lectures for review as those in the FC group.

Post-Class Evaluation and Data Collection

Two weeks after the class, a post-quiz was given to all students that originally participated in both the FC and TLC learning models. The post-quiz consisted of fifty multiple-choice questions from the SYSU Undergraduate Education Committee item bank, and was about a disaster generating fifty casualties. The disaster involved a Sarin nerve agent release after an explosive incident.

In addition, after the post-quiz, a ten-victim, mock MCI scenario was created to test the performance of SFT. It was demonstrated by a 90-second video which described a motor vehicle collision involving two buses and two cars on a highway. The drills were made as realistic as possible with noise and sirens. The victim cases, as well as the 'gold-standard' triage category, were co-designed by the three educators with training certificates, and were vetted by two disaster medicine experts from SYSU.

The victim composition included two 'dead,' one 'expectant,' two 'immediate,' one 'delayed,' and four 'minimal' cases. Each victim was recreated by volunteers given appropriate moulage and symptom coaching for their patterns of injury. Given the real-world differences between moulage and the actual injuries, we also provided traumatic condition cards appended to each victim, detailing all physical examinations and symptoms. Each student went through the simulation independently along with the instructor who recorded time to triage completion and triage categorization. When Life-Saving Intervention (LSI) was needed, the students only needed to apply an LSI card to the victim and the instructor would give results of the LSI. The overall triage accuracy, case specific triage accuracy, types of triage errors, and triage completion time were recorded for each student.

TABLE 1

Demographic information of students who attended the course of mass casualty triage

	FC (n = 51)	TLC (n = 52)	*P*-value
Age (years)	24.55 ± 1.14	24.52 ± 1.0	0.888
Gender			0.378
male	25	30	
female	26	22	
GPA	3.48 ± 0.43	3.45 ± 0.39	0.686
Pre-test	75.39 ± 10.90	77.98 ± 12.26	0.260

Abbreviations: FC, Flipped Classroom; TLC, Traditional Lecture-based Classroom; GPA, Grade Point Average

At the end, the scores from the post-quiz, overall triage accuracy, case specific triage accuracy, types of triage errors, and triage completion time of the SFT were compared to evaluate the difference between FC and TLC groups. After these assessments, students were required to report how much preparation time they had spent for the class and how much review time they had for the post-tests. To conclude, an anonymous questionnaire was also conducted to determine the students' satisfaction with the respective teaching methods they had experienced by grading between 1 to 10 points.

Statistical Analysis

Descriptive statistics were summarized using means and standard deviations, or median (interquartile range). Independent sample t-tests were used to compare the age, grade point average, pre-test scores, and time spent outside of class. Wilcoxon rank tests were used to compare grades of students' perspectives, post-quiz scores, and triage completion time. Chi-square tests were used to compare the proportion of gender, proportion of triage errors, and triage accuracy between the two groups. Statistical tests and graphs were run on GraphPad Software (GraphPad Software Inc., LaJolla, California, USA). Statistical significance was accepted at $P < 0.05$.

RESULTS

Demographic Information

There were 51 students assigned to the FC, and 52 students assigned into the TLC. The class attendance rates of both groups were 100%. The ages, gender, previous GPA, and pre-class test scores for the two groups were comparable (Table 1).

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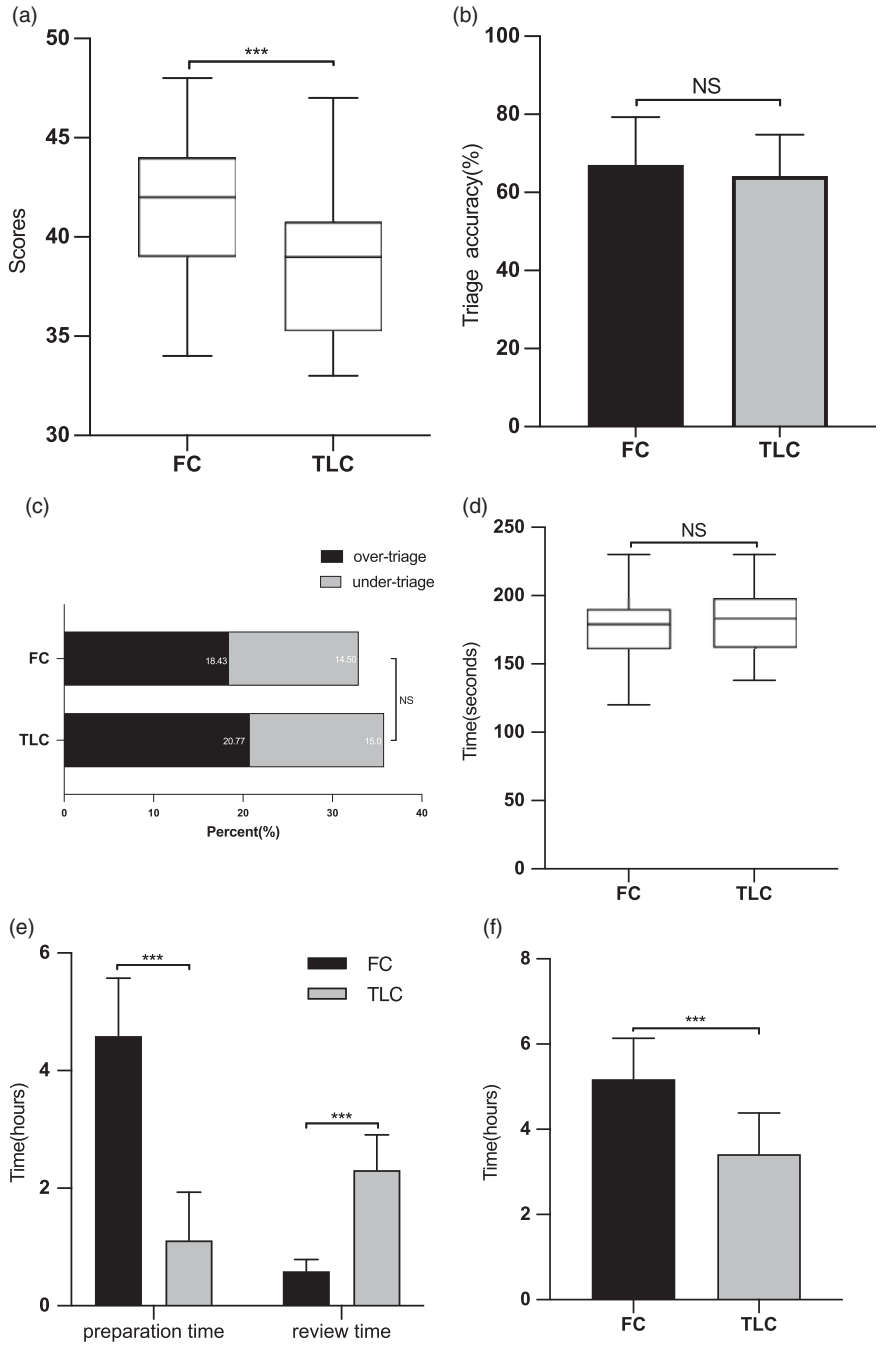
FIGURE 3

Feedback from Students Taking FC Compared to Those Taking the TLC.



(a) Comparison of post-quiz scores. ***p<0.001. (b) Comparison of overall triage accuracy. (c) Comparison of types of triage errors. (d) Comparison of triage completion time in simulated field triage. (e) Comparison of pre-class preparation time and post-class review time. ***p<0.001. (f) Comparison of total time spent outside of class. ***p<0.001. Abbreviations: FC, flipped classroom; TLC, traditional lecture-based classroom; NS, not significant.

Classroom Effectiveness

In the post-quiz, the median (IQR) scores of the 50 multiple-choice questions achieved by students from the FC and TLC groups were 42 (5) and 39 (5.5), respectively. A significant difference was found between the two groups ($P < 0.001$) (Figure 3[a]).

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TABLE 2

Comparison of case specific triage accuracy between the FC and TLC groups

Case Number	Triage accuracy (%)		
	FC	TLC	*P*-value
1	76.47	78.85	0.772
2	80.39	78.85	0.846
3	62.75	51.92	0.267
4	64.71	67.31	0.780
5	58.82	59.62	0.935
6	62.75	67.31	0.627
7	68.63	67.31	0.886
8	74.51	61.54	0.158
9	64.71	65.38	0.942
10	56.86	44.23	0.120

Abbreviations: FC, Flipped Classroom; TLC, Traditional Lecture-based Classroom

In the SFT, overall triage accuracy was 67.06% for FC, and 64.23% for TLC students (Figure 3[b]). Over-triage and under-triage errors occurred in 18.43% and 14.50% of the FC group, respectively. The TLC group had a similar pattern of 20.77% over-triage and 15.0% under-triage errors (Figure 3[c]). No significant difference was found regarding overall triage accuracy ($P = 0.339$) or triage errors ($P = 0.619$) between the two groups. The median (IQR)time to triage completion for FC and TLC students were 179.0 (29.20) seconds and 183.0 (36.0) seconds, respectively ($P = 0.144$) (Figure 3[d]). There was no significant difference in case specific triage accuracy between the two groups (Table 2).

The Distribution of Time Spent Outside of Class

Figure 3(e)(f) demonstrate the distribution of time spent outside of class. The pre-class preparation times of students in both the FC and TLC groups were 4.59 ± 0.98 hours and 1.11 ± 0.82 hours, respectively. The post-class review times of students in both the groups were 0.59 ± 0.20 hours and 2.31 ± 0.60 hours, respectively. Students in the FC spent much more time on the assigned preparatory work ($P < 0.001$), but less time for review work after the class ($P < 0.001$). With regard to total time spent outside of class, the students in the FC group had an average of 5.18 ± 0.96 hours, which is significantly more than those in the TLC group (3.42 ± 0.97 hours) ($P < 0.001$).

Questionnaire

Table 3 compares students' perspectives between the flipped and traditional lecture-based classrooms. Students in the FC group gave higher points for that "it was generally a good class" ($P = 0.012$), "stimulate learning initiative and motivation" ($P = 0.003$), "improve cooperation and communication ability" ($P < 0.001$), "help achieve a more comprehensive understanding of knowledge" ($P = 0.032$), and "hope this teaching method can be applied in the other courses" ($P < 0.001$). However, they also agreed that the FC occupied too much of their spare time ($P = 0.041$) and gave too much added burden and pressure ($P = 0.029$) to their study schedule. When comparing whether the classroom helped performance in the SFT or not, the difference between both groups was insignificant ($P = 0.629$).

TABLE 3

Comparison of students' perspectives between the FC and TLC groups in the course of mass casualty triage

No.	Items	FC	TLC	*P*-value
1	It was generally a good class	8.42 ± 1.54	6.73 ± 0.98	0.012
2	This class stimulated my initiative and motivation in learning	8.19 ± 0.88	6.52 ± 1.15	0.003
3	This class improved my cooperation and communication ability	8.77 ± 1.18	4.19 ± 0.57	<0.001
4	This class helped me achieve a more comprehensive understanding of the knowledge	8.61 ± 1.25	6.63 ± 0.71	0.032
5	This class helped me perform well in the simulated field triage	7.51 ± 1.02	7.09 ± 0.93	0.629
6	I hope this teaching method can be applied in the other courses	8.97 ± 0.53	5.75 ± 1.15	<0.001
7	This class occupied too much of my spare time	7.95 ± 0.84	6.31 ± 1.13	0.041
8	This class gave me too much burden and pressure	8.73 ± 1.25	6.89 ± 0.96	0.029

Abbreviations: FC, Flipped Classroom; TLC, Traditional Lecture-based Classroom.

Discussion

This study was a further exploration into the effectiveness and suitability of the FC approach in undergraduate medical education. The scores of post-class quiz revealed that students from the FC group performed better on the content covered by the module on MCT. This result fits into the established landscape of FC studies, which have shown that it is effective in helping students comprehensively master the knowledge and demonstrate increased academic performance, as measured by improved examination results or course grades, in comparison with conventional teaching.[1,19,20] These promising results can be explained by the demonstration that the FC methodology promotes the integration of independent learning, provides authentic and group-based classroom study, offers more

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efficient student-teacher interactions, and emphasizes the output of knowledge from students.[1,7,11]

Notably, time spent outside of class was significantly different between the two groups. Students in the FC spent much more time on the assigned preparatory work, but less time for review work after the class. What's more, we also found that the FC students spent much more time on the subject outside of class. This important finding might, in part, explain why students profited more from the FC approach in post-quiz, because spending more time means students can get more knowledge and deeper understanding. However, spending more time out of class also means it will occupy too much of their spare time. The amount of assigned preparatory work may also be the reason why there was a significant difference with regard to 'burden and pressure' between groups. Nevertheless, according to the survey, students in the FC still appeared to be much more satisfied with this specific approach, since it increased their motivation, improved their cooperation and communication abilities, and helped them perform well in the post-quiz. Efficient and timely triage of casualties is a critical step during MCIs or disasters. There are currently different modalities for the general qualitative assessment of triage efficiency, such as written paper tests, tabletop exercises, computer software-based simulation programs, and mock disaster drills.[21] In this study, we created a mock mass casualty scenario to further assess students' actual practical competencies for triage, since simply comparing written test results is not enough to evaluate the educational effects of the FC method.[6]

However, the differences were insignificant in overall triage accuracy, case specific triage accuracy, types of triage errors, or triage completion time in the SFT. Grades from the survey, for determining whether the teaching approaches they received respectively help their performance in the SFT or not, were also statistically insignificant. SFT performance of the FC students didn't show any predominance in comparison with the TLC students, even though they acquired higher scores from the post-quiz. This might reflect the indispensability of practice for improving students' learning effectiveness, and understanding the knowledge presented. However, it was a single center trial with limited samples, this study limitation which might cause biased results. A multicenter study with larger samples is needed for further evaluation.

CONCLUSIONS

In the course of MCT training, the FC approach could enhance course grades in the post-quiz, and improve students' satisfaction with the class. However, no significant difference was found in SFT triage accuracy between the FC and TLC groups.

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Author Contributions

Ziyu Zheng, Shiwen Yuan, and Mingcheng Huang contributed equally to the work.

Conflict of Interest Statement

No potential conflict of interest was reported by the authors.

Supplementary material

To view supplementary material for this article, please visit https://doi.org/10.1017/dmp.2020.162.

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