Implementation of flipped classroom combined with case- and team-based learning in residency training

Chun Ding,* Qin Wang, Jingling Zou, and Kewei Zhu
Department of Orthopaedic, The Second Xiangya Hospital of Central South University, Changsha, China

Abstract

The core problem of Chinese resident doctor training is that medical educators present content in an attractive teaching mode to make students more motivated to learn and improve their clinical thinking ability, humanistic care, and practical ability. The traditional classroom mode of teaching cannot meet the needs of modern medical education. The purpose of this study is to explore the benefits and challenges of the flipped classroom (FC) combined with case- and team-based learning (FC-CTBL) for residency training. In this study, 60 junior surgical residents of Xiangya Medical College were enrolled. "Diabetic foot" was selected as the content of this study. Residents were divided into an FC-CTBL group and an FC group. FC-CTBL and FC were compared on the basis of residents’ feedback questionnaires, residents’ learning burden, test scores from a pre-quiz, and objective structured clinical examinations (OSCE). Residents were more satisfied with the FC-CTBL model compared with FC. In the FC-CTBL group, more participants said that the course improved their teamwork skills, analytical skills and their confidence in tackling unfamiliar problems. Residents in the FC-CTBL group also spent significantly less time preparing for class and performed better in the OSCE than those in the FC group. FC-CTBL stimulates residents’ learning motivation, decreases their workload, improves their performance in the OSCE and may help to enhance clinical thinking and teamwork skills. The FC-CTBL approach is a good option for residency training.

diabetic foot; FC-CTBL; OSCE; resident doctors

INTRODUCTION

The ways in which to mobilize the initiative of Chinese resident doctors to improve their clinical thinking ability, humanistic care, and practical capabilities have been core issues of Chinese residents’ training (1). The traditional classroom teaching model can no longer meet the needs of modern medical education. Therefore, the reform of teaching models, with question-based learning (2–4), case-based learning (CBL) (5), team-based learning (TBL) (6), and flipped classroom (FC)-based learning (7) continues to emerge. FC was first proposed by Lage et al. (8) in 2000. In FC, students take the initiative to learn lessons before class and solve problems in the process of classroom discussion and cooperation (9–11). Students finish self-study in their spare time. In class, teachers are responsible for guiding students to communicate, answering students’ questions face to face, and allowing the classroom to be used for active learning (12).

The literature on the use of the FC in health science education has increased over the past few years. However, much of the work was done in the fields of pharmacy and nursing (13–18).

Therefore, more research focusing on overall (undergraduate, graduate, and continuing) medical education is needed. There is no uniform way to design the details of an FC class. Some studies have noted an increase in student workload related to autonomous pre-class learning, particularly in the time taken to watch lengthy video lectures. Some students in an FC class complained that they spend much more time before class (19–22) and have poor absorption and understanding during class, and what they learn is different from what appears in actual clinical cases (8, 19, 21, 23). Therefore, we need more advanced teaching methods to supplement and improve FC. CBL is a tool that matches clinical cases in a health care-related field with a lot of specialized knowledge in that area to improve clinical performance. Thistlewaite et al. (5) explained: “The goal of CBL is to prepare students for clinical practice, through the use of authentic clinical cases. It links theory to practice, through the application of knowledge to the cases, using inquiry-based learning methods”.

TBL is a group teaching method that guides students through a series of activities, including individual work, teamwork, and immediate feedback to improve teamwork skills, learn efficiency, and reduce individual learning burden (24). The TBL method was invented by Dr. Larry Michaelsen in the 1970s (24). Health professions are among the biggest adopters of TBL, which is used to train medical students to think critically and apply concepts to practice (25). Thus, CBL and TBL are complementary to FC and remove the shortcomingsof the heavy learning burden in traditional FC, introducing clinical cases to enrich the teaching mode of FC. There are a few
reports about how FC, CBL, and TBL have been implemented into the curriculum of teaching courses (7, 26, 27). However, to our knowledge, the majority of the work in this area has been performed in undergraduate medical education. It is unclear whether the findings can be extended to residency training. Moreover, little research has combined these learning strategies together into residency training. Therefore, we designed a new teaching method that combines FC with CBL (FC-CTBL), and extends the method to Chinese resident doctor training. The aim of this study was to evaluate the effectiveness of the FC-CTBL approach as applied to Chinese resident doctor training.

## METHODS

### Study Design and Participants

This study was approved by the Ethics Committee of the Second Xiangya Hospital of Central South University. A total of 60 junior surgical residents were enrolled in the study. Using Excel to generate random numbers, 60 residents were randomly assigned to either the FC-CTBL group (n = 30) or FC group (n = 30). Figure 1 shows the flowchart summarizing the FC-CTBL and FC.

### FC-CTBL Study Design

On the basis of CBL, an authentic clinical case of diabetic foot (see Supplemental Material S1, https://doi.org/10.5281/zenodo.4152900; all supplemental materials can be found at this site) from the orthopedic ward was provided to residents before class. The teacher met with the residents to share instructions on communication skills with patients, medical history collection, and physical examination. On the basis of TBL, the residents were divided into four groups. Residents in each group worked together on asking about medical history, performing physical examinations, and analyzing the examination results to obtain diagnoses, select appropriate treatment methods, and apply what they have learned to analyze and solve clinical problems. The relevant lecture videos and supplemental materials for the course were sent to the residents by Internet for studying outside of class. Residents were required to search and review relevant course materials via the Internet, and to raise problems and difficulties encountered during study. Each group had a topic and worked together to prepare a corresponding PowerPoint presentation (PPT) for class discussion. In class, the representatives of the first group made a PPT presentation of clinical manifestations, the second group made a presentation on anatomy and pathogenesis, the third group made a presentation on diagnosis and differential diagnosis, and the fourth group made a presentation on prevention and treatment. Subsequently, the teacher summarized the anatomical and pathological mechanisms, clinical manifestations, diagnoses, treatment, and prevention of the disease in combination with the supplied case. Finally, the evidence and sources of evidence-based science were supplied (see Supplemental Material S2), and the teacher guided the residents in discussions.

### FC Study Design

Both groups were taught by the same teacher. Before the class, the teacher prepared the relevant lecture videos and supplemental materials, which were consistent with the FC-CTBL group. Residents in the FC group needed to view material on their own time and make a PPT about the clinical manifestations of the diabetic foot, its anatomy and pathogenesis, diagnosis, and treatment. In class, five residents were selected to make a PPT presentation for the whole case. After that, as with the FC-CTBL study design, the teacher summarized the anatomical and pathological mechanisms, clinical manifestations, diagnosis, treatment, and prevention of the disease. Finally, the same evidence and sources of evidence-based science were also supplied, and the teacher guided the residents in discussions.

### Data Collection

A pre-quiz of 20 questions was conducted before the classes to evaluate residents’ baseline knowledge of diabetic foot. After class, all of the residents completed a feedback questionnaire that was modified from the Ramsden course experience questionnaire (CEQ) (28) and the Biggs study process questionnaire (29).

In addition, all residents used the clinical thinking ability scale for a self-evaluation before and after class. All residents were required to report how many hours they had spent on their preparation and review for the lesson. Objective structured clinical examinations (OSCE) were conducted to evaluate residents’ understanding of the diabetic foot course. The OSCE is an examination in which residents are given a structured scenario and are expected to develop evaluations and plans based on structured cases. We used standardized patients in the evaluation process and assessed each item according to the case of diabetic foot cases. Residents were assessed in five stations: clinical data collection, medical record writing, case analysis, clinical operation skills, and X-ray reading. A total of 100 points were given for each of the five areas (see Supplemental Material S3).

### Statistical Analysis

Demographic data of the residents were analyzed using an independent samples t-test or χ²-test. The pre-test scores, the hours spent on class preparation, and the review of the OSCE were compared between the two groups by an independent t-test. For the results of the OSCE, we applied a Bonferroni adjustment for multiple comparisons to all the pairwise comparisons, a P value < 0.05/5 = 0.01 was considered to be significant. All questionnaire data were analyzed using the Mann-Whitney U test. The residents’ self-evaluation of their clinical thinking ability before and after class were also analyzed using a paired t-test. P < 0.05 was considered statistically significant.

### RESULTS

#### Participants’ Demographic Data

This study consisted of 60 junior surgical residents: 30 were in the FC-CTBL group, and 30 were in the FC group. The mean age of the FC-CTBL group students was 23.53 ± 1.479 yr (means ± SD) and of the FC group, the mean age of students was 23.1 ± 1.322 yr. There was no significant difference in gender and average age between the two groups. All data are summarized in Table 1.
Residents’ Perspectives, Self-Perceived Competence Survey

We compared residents’ perspectives and self-perceived competence between the FC-CTBL and FC groups, respectively. As shown in Table 2, there were significant differences between the FC-CTBL group and the FC group in the questionnaire concerning teamwork ability ($P = 0.019$), analytical ability scale ($P < 0.0001$), confidence in tackling unfamiliar problems ($P < 0.0001$), and workload ($P < 0.0001$).

Residents’ self-perceived competence was compared after using the FC-CTBL and FC methods, shown in Table 3. Compared with the FC group, more residents agreed that the FC-CTBL helped improve their communication ability ($P = 0.003$), clinical thinking ability ($P = 0.011$), ability to acquire knowledge ($P = 0.006$), ability to give presentations and express opinions ($P = 0.007$), and ability in scientific thinking ($P = 0.014$).

The results of the residents’ self-evaluation of their clinical thinking before and after class are shown in Figure 2A.
Table 1. Demographic information of junior surgical residents who participated in diabetic foot study

|            | FC-CTBL     | FC          | Statistics | P Value |
|------------|-------------|-------------|------------|---------|
| Number of students | 30          | 30          |            |         |
| Age, yr    | 23.533 ± 1.479 | 23.1 ± 1.322 | t = 1.196  | 0.236†  |
| Sex, male/female | 13/17       | 10/20       | χ² = 0.635 | 0.426†  |

Age is expressed as the means ± SD. FC, flipped classroom; FC-CTBL, flipped classroom combined with case- and team-based learning. *Independent sample t-test. †χ²-test.

Data were assigned according to Likert scale, where a higher score indicates better behavior on clinical thoughts, and the scores are listed as followed: great = 5, good = 4, normal = 3, not good = 2, bad = 1. There was no significant difference in scores of clinical thinking scale between the before class and after class in FC group (84.2 ± 9.789 vs. 85.933 ± 9.53; P = 0.49). The scores of clinical thinking scale were increased in the FC-CTBL group (87.533 ± 9.933 vs. 93.367 ± 8.747, P = 0.019).

Residents’ Workload

We took preclass preparation time and after-class review time as indicators to evaluate residents’ workload. As shown in Figure 2B, residents in the FC-CTBL group spent significantly less time preparing for classes than those in the FC group (61.667 ± 8.841 min vs. 132.667 ± 22.312 min; P < 0.0001). There was no significant difference in after-class review time between the FC-CTBL and FC groups (63.667 ± 12.243 min vs. 67.167 ± 13.938 min; P = 0.306). The total time in FC-CTBL was significantly decreased (125.333 ± 14.077 min vs. 199.833 ± 27.652 min; P < 0.0001).

Residents’ Scores on Quizzes and Clinical Skills

No statistical differences were found in the preclass quiz scores between the FC-CTBL and FC groups (54.667 ± 12.03 vs. 57.333 ± 11.725; P = 0.388; Fig. 2C). Figure 2D shows the OSCE results. Significant differences were found between the FC-CTBL and FC groups in clinical data collection (79.867 ± 7.477 vs. 70.1 ± 5.938; P < 0.0001), medical record writing (84.4 ± 6.234 vs. 71.6 ± 8.27; P < 0.0001), case analysis (84.8 ± 6.445 vs. 76.033 ± 5.869; P < 0.0001) and clinical operation skills (81.033 ± 7.407 vs. 72.833 ± 6.576; P < 0.0001). There was no significant difference in X-ray reading (72.533 ± 9.912 vs. 68.167 ± 12.499; P = 0.139).

Table 2. The questionnaire survey was adopted to compare the learning feelings of the two groups of junior surgical residents

| Items                                                                 | Group       | 1    | 2    | 3    | 4    | 5    | Mann-Whitney U test | P Value | Effect Size |
|-----------------------------------------------------------------------|-------------|------|------|------|------|------|--------------------|---------|-------------|
| The class has helped me develop my ability to work as a team member.  | FC-CTBL     | 1610 | 106  | 310  | 13   | 01   | 0.019              | 0.286   |
| The class has sharpened my analytical skills.                        | FC-CTBL     | 1510 | 76   | 69   | 13   | 12   | 0.019              | 0.201   |
| As a result of my degree course, I feel confident about tackling unfamiliar problems. | FC-CTBL     | 2143 | 612  | 03   | 02   | 00   | 0.002              | 0.3787  |
| The class has developed my problem-solving skills.                   | FC-CTBL     | 197  | 910  | 26   | 05   | 02   | 0.000              | 0.452   |
| The workload is too heavy.                                           | FC-CTBL     | 110  | 37   | 410  | 103  | 120  | 0.000              | 0.606   |
| I have usually had a clear idea of where I am going and what is expected of me in this class. | FC-CTBL     | 1813 | 1111 | 13   | 03   | 00   | 0.088              | 0.208   |
| It is always easy to know the standard of work expected.             | FC-CTBL     | 236  | 35   | 313  | 13   | 03   | 0.000              | 0.539   |
| The staff made it clear right from the start what they expected from students. | FC-CTBL     | 1912 | 1013 | 13   | 02   | 00   | 0.04               | 0.251   |
| The class is intellectually stimulating.                             | FC-CTBL     | 149  | 116  | 53   | 08   | 04   | 0.008              | 0.325   |
| The class administration is effective in supporting my learning.     | FC-CTBL     | 134  | 910  | 65   | 28   | 03   | 0.002              | 0.377   |
| My class has stimulated my enthusiasm for further learning.          | FC-CTBL     | 155  | 65   | 716  | 13   | 11   | 0.002              | 0.370   |
| Where it was used, information technology helped me to learn.        | FC-CTBL     | 116  | 49   | 98   | 67   | 00   | 0.491              | 0.084   |
| I feel part of a group of students and staff committed to learning.  | FC-CTBL     | 195  | 116  | 010  | 05   | 04   | 0.000              | 0.596   |
| I feel I benefit from being in contact with active researchers.      | FC-CTBL     | 109  | 1210 | 66   | 25   | 00   | 0.438              | 0.095   |

Likert scale: 1, strongly agree; 2, agree; 3, neutral; 4, disagree; 5, strongly disagree. Effect size is calculated by test statistic divided by the root of sample size (small effect: 0.1 ≤ r ≤ 0.3, medium effect: 0.3 ≤ r ≤ 0.5, large effect: r > 0.5).
DISCUSSION

This report investigated the effectiveness and suitability of the combination of FC, CBL and TBL learning methods in residency training. We chose diabetic foot as the research topic because it has many typical clinical symptoms and signs, it is not too complicated to prepare at home without a tutor, and we can use typical cases from our ward. The American Diabetes Association defines the diabetic foot as the anatomical area below the malleoli in a person with diabetes mellitus. The diabetic foot may be defined as a group of syndromes in which neuropathy,
ischemia, and infection lead to tissue breakdown, resulting in morbidity and possible amputation (30). In addition, the pathological mechanism of diabetic foot is complex, and the treatment method is still inconclusive. Residents can improve their scientific thinking ability by consulting, synthesizing, and analyzing literature.

Residents were more satisfied with the FC-CTBL model compared with FC for the follow reasons. First, according to the results of questionnaire survey, more students in the FC-CTBL group report that the class is intellectually stimulating. In the FC-CTBL model, an authentic clinical case was provided to residents before class that stimulated residents’ enthusiasm for learning. Residents took the initiative to ask about medical history, finish the physical examination, and analyze the test results to obtain a diagnosis and choose the appropriate treatment method. The FC-CTBL teaching model not only promoted residents’ enthusiasm for active learning, but also improved their clinical skills. The FC-CTBL teaching model revealed the pathophysiological mechanism, clinical manifestations, diagnosis, and treatment of diseases through typical cases, transformed vague concepts in the textbook into vivid clinical knowledge, and improved the residents’ clinical ability to conduct medical history collection, physical examination, and diagnostic analysis. Therefore, the residents in the FC-CTBL group believed that their clinical thinking ability, ability to acquire knowledge, and analytical skills were improved.

Second, according to a previous report, the benefits of CBL also included providing learners with clinically relevant knowledge and skills, providing teachers with more input in the direction of learning, and guiding deeper learning (5, 26). Compared with the FC group, more residents in the FC-CTBL group reported that they knew what their teacher expected of them and the standard of work expected. They believed that the class was intellectually stimulating and stimulated their enthusiasm for further learning.

Third, TBL is an effective way of learning (7, 31, 32). Residents in the FC-CTBL group were divided into four groups before class. Each group had a specific learning task, and tasks were assigned among group members. Residents in each group helped each other in the process of self-study. One key to this interactive approach was to learn from others and to help others learn, develop a sense of teamwork, encourage residents to share what they have learned, and achieve common progress through mutual discussion, explanation, and questioning. More residents in the FC-CTBL group believed that their team awareness and teamwork ability had been improved. Complaints about overburden of study were significantly less than those in the FC group. In the FC group, the teacher prepared relevant materials for residents, residents had to watch a lot of videos, and it took a significant amount of time for residents to make PPT presentations by themselves. As a result, more residents in the FC group complained about the heavy study burden and the pressure of being a student in this class. Fewer students in FC group felt the class was intellectually stimulating and had stimulated their enthusiasm for further learning. So, learning that was not combined with clinical cases were likely more boring. Redundant preclass learning materials could easily cause residents to lose focus on their learning; FC takes time and is not efficient. Therefore, fewer residents in FC knew the standard of work expected (19–21).

Finally, we compared the preclass preparation time and postclass review time of the residents in the two groups. We found that the preclass preparation time of the residents in the FC-CTBL group was significantly shortened for each resident, primarily due to the allocation of learning tasks in the preclass groups. However, the preclass preparation time of the FC group increased significantly, and more residents complained about the heavy study burden, which was consistent with previous reports (19–22). The heavy study burden was also a bottleneck restricting the widespread adoption of FC. The introduction of CBL and TBL in FC can significantly reduce the learning burden of residents and is a beneficial supplement and improvement to FC.

In addition, we compared the residents’ scores from the quizzes between the two groups. Prequiz results confirmed there was no significant difference in baseline knowledge of diabetic foot between the two groups. However, the OSCE scores of the FC-CTBL group were significantly better than those of the FC group. According to many previous reports, the OSCE is an objective evaluation of the clinical performance of medical students’ comprehensive ability assessment model, so we select the OSCE as the evaluation index (33). We set up five stations for assessment: clinical data collection, medical record writing, case analysis, clinical operation skills and X-ray reading. The residents in the FC-CTBL group received training on medical history collection, physical examination, examination result analysis, disease diagnosis analysis, and treatment strategy for real cases in the preclass preparation stage, which was the reason for their high scores. The residents’ clinical thinking ability was strengthened by the study of these clinical cases, while the results of residents’ self-evaluation on clinical thinking ability preclass and postclass were also confirmed.

The advantage of FC-CTBL is that it provides real cases and improves residents’ clinical knowledge, practical behavior, and clinical skills. In practical clinical work, the treatment of patients is a teamwork activity, and it is necessary to train medical students in teamwork and to improve their sense of teamwork. On the basis of the original FC teaching, the FC-CTBL teaching method is introduced on the basis of cases and in the form of teamwork. Compared with FC, FC-CTBL is more effective in the teaching of diabetic foot for residency training.

Study Limitations

There were several limitations of our research. First, although our research confirmed that FC-CTBL is effective in teaching diabetic foot, our research on FC-CTBL was limited to a single course. To better evaluate the effectiveness of FC-CTBL, this model needs to be implemented more broadly across multiple courses or the entire curriculum. Second, several evaluations of the FC-CTBL model were based on self-assessment from the residents, such as clinical thinking and teamwork skills. An updated evaluation system that includes measures of core competencies other than knowledge acquisition will be warranted to better evaluate the effectiveness of FC-CTBL.
CONCLUSIONS

Overall, compared with FC, the FC-CTBL approach could be a better option in the teaching of diabetic foot to residents. FC-CTBL stimulates residents’ learning motivation, decreases their workload, improves their performance in the OSCE, and may help to enhance clinical thinking and teamwork skills. The FC-CTBL approach needs to be implemented more broadly across multiple courses or the entire curriculum and be further optimized in terms of the evaluation system of residents’ performance.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

K.Z. conceived and designed research; C.D., Q.W. and K.Z. performed experiments; C.D. and J.Z. analyzed data; J.Z. interpreted results of experiments; C.D. and Q.W. prepared figures; C.D. and K.Z. drafted manuscript; K.Z. edited and revised manuscript; K.Z. approved final version of manuscript.

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