Effectiveness of team-based learning on academic performance in an electric circuit theory course for health sciences students

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ABSTRACT: Team-based learning (TBL) was applied twice in an electric circuit theory course for health sciences freshmen at a medical university in Taiwan. In addition to performing the individual readiness assurance test (iRAT) and the team readiness assurance test (tRAT), the individual review test (iRET) was performed at the end of these two classes. The questions in the iRET were similar to those in the iRAT and tRAT. However, the iRAT and tRAT contained multiple choice questions, but the iRET comprised problem-solving questions, i.e. writing down calculation procedures was required. In these two occasions of using TBL, tRAT scores were higher than iRAT scores. The iRET score was lower than the iRAT score in the first TBL, but the former was higher than the latter in the second TBL. Furthermore, the iRAT score in the second TBL was higher than that in the first TBL. According to the questionnaire survey, students felt positive about TBL's effectiveness in promoting text comprehension, inspiring active learning and improving communication skills.

INTRODUCTION

Team-based learning (TBL) was originally proposed by Michaelsen in the late 1970s and has been applied in many fields, e.g. nursing, anatomy, pathology, medicine, pharmacy, accounting, and others [1-7]. It has been shown that TBL can promote study motivation, self-learning skill, class engagement, teamwork perceptions and academic performance. Furthermore, TBL has been shown to be an effective method to transform teacher-centred passive learning into student-centred active learning [8][9].

There are several well-recognised steps in TBL. At the beginning of the class, students were divided into several small groups. Some pre-reading materials were assigned and students were supposed to complete the assignment before attending the class. Once getting into the classroom, students first take an individual readiness assurance test (iRAT). Then, students take a team readiness assurance test (tRAT) using an immediate feedback assessment technique (IF-AT) as a group. The tRAT has the similar questions as the iRAT. Students can know the right answers in the tRAT immediately.

After the tRAT, there is a chance for students to *appeal*, to explain why they have different answers from the correct answers. Instructors can also quickly browse the results of tRAT and stress the main concepts of the questions, which were answered wrongly by most of the groups. Afterwards some activities for advanced group discussion to apply the concepts of the pre-reading materials and peer-evaluation were performed. Students in the same group may have different scores in TBL depending on peer-evaluation scores based on their contributions to the groups [10][11].

Electric circuit is a required three-credit course for freshmen in the Department of Medical Imaging and Radiological Sciences (MIRS) at Kaohsiung Medical University (KMU). The contents include direct current (DC) circuits, alternating current (AC) circuits and devices. In this course, students learn how to analyse electric circuits, i.e. to calculate the voltages across some elements and the currents through some branches in electric circuits, and also to troubleshoot the electric circuits. The textbook used was *Electronics Fundamentals: Circuits, Devices, and Applications* [12].

Generally speaking, AC circuits are more difficult than DC circuits for students to fully understand. The contents in AC circuits include resistor-capacitor (RC) circuits, resistor-inductor (RL) circuits and resistor-inductor-capacitor (RLC) circuits. There are similar to the structures of the contents for RC and RL circuits shown in Table 1. Understanding RC and RL circuits is helpful in understanding RLC circuits. The contents of RLC circuits are listed in Table 2.

O'Connell has shown that TBL is effective in assisting learning on both technical contents and several professional skills in a sophomore-level electric theory sequence [13]. The aim of this study was to investigate whether TBL can improve the academic performance of health sciences students on RC, RL and RLC circuits.

Table 1: Contents of RC and RL circuits.

RC Circuits	RL Circuits
Basic capacitors	Basic inductors
Types of capacitors	Types of inductors
Series capacitors	Series inductors
Parallel capacitors	Parallel inductors
Capacitors in DC circuits	Inductors in DC circuits
Capacitors in AC circuits	Inductors in AC circuits
Capacitors applications	Inductors applications
Sinusoidal response of RC series circuits	Sinusoidal response of RL series circuits
Impedance and phase angle of RC series circuits	Impedance and phase angle of RL series circuits
Analysis of RC series circuits	Analysis of RL series circuits
Analysis of RC parallel circuits	Analysis of RL parallel circuits
Analysis of RC series-parallel circuits	Analysis of RL series-parallel circuits
Power in RC circuits	Power in RL circuits
Applications	Applications
Troubleshooting	Troubleshooting

Table 2: Contents of RLC circuits.

RLC Circuits
Impedance and phase angle of RLC series circuits
Analysis of RLC series circuits
Series resonance and filters
Analysis of RLC parallel circuits
Parallel resonance and filters
Applications

METHODS

At the beginning of the electric circuit class in the 2013 spring semester, the class instructor introduced how the TBL teaching strategy should be performed and students were divided into several small groups. There were seven groups and each group had seven members. TBL was performed twice in the course during the 11th and 14th weeks. By that time, students were already familiar with each other, and had acquired some basic knowledge about electrical circuits. The first TBL covered series and parallel RC circuits and the second TBL consisted of RC troubleshooting, RL troubleshooting, RLC series circuits and RLC parallel circuits.

The teaching materials (TM) about these two units were arranged as PowerPoint (PPT) slides, and were uploaded to an e-learning platform supplied by the University. This platform was open only to students taking the class. Students were asked to pre-read the materials before class. In the class, an iRAT was performed first, and followed by a tRAT. There were 10 multiple choice items in the iRAT. In the first TBL, the tRAT had the same 10 multiple choice items as the iRAT taken for 25 minutes. In the second TBL, the tRAT had an extra five advanced multiple choice items in addition to the same 10 multiple choice items in the iRAT. In addition, crash and win cards were used for the tRAT to show the correct answers immediately.

If the correct answer was scratched the first time, 10 points were obtained, five points and 2.5 points were obtained, respectively, if the correct answers were scratched the second or third time. No points were obtained if the correct answer was obtained the fourth time. Students were reminded that they needed to be familiar with the calculation procedures during the tRAT. Afterwards, there was time to appeal. After the appeals, an iRET was performed. There were five items in the iRET. Instead of multiple choices, students needed to write down the calculation procedures carefully in the iRET. After the iRET, a survey and a mini-lecture were performed. The flow chart is listed in Table 3.

At the end of the class, a peer evaluation was performed to provide each group member with a weighting number according to each member's contribution. The sum of the weighting numbers for each group was number of group members minus one. Each TBL score was calculated as follows: TBL score = iRAT scores (15%) + tRAT scores (60%) + iRET scores (25%). The grading percentage is listed in Table 3. Each TBL score was 5% of the final grade of this course.

The questionnaire items are listed in Table 4. In the first questionnaire there were 20 quantitative items. Except for the first item, a 6-point scoring system was used: 6: *strongly agree*; 5: *agree*; 4: *slightly agree*; 3: *slightly disagree*; 2: *disagree*; 1: *strongly disagree*. In the second questionnaire, four more quantitative items were added.

Only the iRAT, tRAT and iRET scores of students who completed the two periods of TBL were analysed. Scores of the whole class were expressed in mean ± standard deviation. The tRAT scores were compared with the iRAT scores, and the iRET scores were compared with the iRAT or tRAT scores using paired *t*-test.

The mean scores of the iRAT, tRAT and iRET in the first TBL were also compared with those of the second TBL using paired *t*-test. There was a significant difference if $p < 0.05$. In the first TBL, the contents of the iRET was similar to the iRAT, therefore, the iRAT and tRAT scores with 10 items were compared. In the second TBL, half of the contents of the iRET were similar to the five items of the iRAT and tRAT. The other half of the contents of the iRET were similar to the extra parts of the tRAT. Only the scores of the similar parts among the iRAT, tRAT and iRET were compared. This project was approved by the local Institutional Review Board at KMU.

Table 3: TBL flow chart.

Procedure	1st TBL time (min)	2nd TBL time (min)	Score percentage (%)
iRAT	20	20	15
tRAT	25	40	60
Appealing and mini-lecture	20	25	
iRET	25	25	25
Survey and peer evaluation	10	10	

Table 4: Survey scores.

Items for pre-reading PPT TM	1st TBL	2nd TBL	*p*
The hours I spent	2.76 ± 1.53	2.71 ± 1.66	0.9095
I read textbooks	3.43 ± 1.41	3.88 ± 1.53	0.0552
I reviewed handouts I never had before	4.73 ± 0.98	5.03 ± 1.14	0.1608
I had discussions with classmates	3.40 ± 1.38	3.15 ± 1.52	0.3331
I googled useful information	2.63 ± 1.40	2.47 ± 1.28	0.3046
It felt very difficult	3.83 ± 0.83	3.56 ± 0.96	0.0300*
It felt too heavy	3.70 ± 0.95	3.44 ± 1.05	0.0960
I already had a pre-reading habit	2.55 ± 1.15	2.59 ± 0.86	0.5722
I felt there were difficult items in iRAT	3.39 ± 1.23	3.24 ± 0.87	0.2113
Items for discussing with team members			
I felt it was helpful in understanding the PPT TM	4.35 ± 1.05	4.85 ± 0.70	0.0034*
I was helped and felt happy	4.48 ± 1.15	4.88 ± 0.69	0.0458*
I gave help and felt happy	4.52 ± 1.12	4.68 ± 0.81	0.2564
I felt tRAT became easier	4.32 ± 1.05	4.74 ± 1.05	0.0333*
I did not know how to discuss	3.10 ± 1.35	2.59 ± 1.02	0.0109*
I kept on with discussing after class	2.74 ± 0.89	2.94 ± 1.13	0.5139
I was familiar with team members	3.71 ± 1.04	4.35 ± 0.92	0.0068*
I love team discussion time		4.35 ± 0.92	
I love to have discussions with team members		4.38 ± 0.78	
I wish to make more contribution in the next TBL	5.00 ± 0.82	4.88 ± 0.84	0.5708
I love to study alone	3.58 ± 1.03	3.79 ± 0.95	0.3861
Items for overall TBL			
TBL enhanced my text comprehension	4.23 ± 1.15	4.35 ± 1.07	0.3112
TBL inspired my active learning		4.06 ± 1.10	
TBL improved my communication skills		4.18 ± 1.06	
I would love to try more TBL	4.03 ± 1.11	4.03 ± 1.03	0.9915

* indicates there is significant difference ($p < 0.05$)

RESULTS

The numbers of students who completed the first TBL, the second TBL and both TBLs were 37, 40 and 32, respectively. Only the scores of the students who completed both TBL were analysed. These two periods of TBL scores are listed in Table 5. In the first TBL, the tRAT score was significantly higher than the iRAT ($p < 0.001$). However, the iRET score was significantly lower than the iRAT ($p < 0.05$) or tRAT ($p < 0.001$).

In the second TBL, the tRAT score was also significantly higher than the iRAT ($p < 0.001$). The difference from the first TBL was that the iRET score was significantly higher than the iRAT ($p < 0.001$). As in the first TBL, the iRET score was significantly lower than the tRAT ($p < 0.001$).

When comparing the scores between these two periods of TBL, the iRAT, tRAT and iRET scores of the second TBL were all higher than those of the first TBL, respectively. There were significant differences between the first and the second TBLs in the iRAT, tRAT and iRET scores, respectively ($p < 0.001$).

Table 4 shows the questionnaire results. Students spent about 2.74 hrs pre-reading PPT TM. While pre-reading PPT TM, students reviewed the PPT TM given before. Most students did not have pre-reading habits. However, the scores of *felt difficult* went down significantly, demonstrating that the pre-reading led to improvements. While having discussions with team members, students felt helpful and happy, and the scores of the second TBL were significantly higher than those of the first TBL.

Students became more familiar with their team members at the time of the second TBL than the first TBL. However, students did not hold discussions with team members much after class. Overall, students felt positive about TBL's effectiveness in enhancing text comprehension, inspiring active learning, and improving communication skills. Students loved their discussions with team members, enjoyed team time and desired to try more TBL.

Table 5: TBL scores.

Procedure	1st TBL	2nd TBL
iRAT	51.3 ± 27.1	63.8 ± 23.5
tRAT	89.4 ± 11.3	95.9 ± 7.1
iRET	40.4 ± 33.1	79.6 ± 21.8

DISCUSSION

Two periods of TBL were performed in an electric circuit course. The iRAT, tRAT and iRET scores of TBL were analysed. In these two periods of TBL, the tRAT scores were significantly higher than the iRAT scores, demonstrating that team work could increase the academic performance in the electric circuit course. The iRAT, tRAT and iRET scores of the second TBL were higher than those of the first TBL shows that more TBL experiences could promote the academic performance in this course.

The iRET score in the first TBL was lower than the iRAT score. This might be because of the different forms of the iRAT and iRET. While the iRAT consisted of multiple choices questions, the iRET consisted of solving problems. Nonetheless, it was not always true, because the iRET score in the second TBL was higher than the iRAT score. It demonstrates that team work and more TBL experiences could better improve individuals' academic performance.

In these two periods of TBL, the iRET score was significantly lower than the tRAT score. This result demonstrates that students had to understand some of the details when they tried to write down the results step-by-step rather than simply picking an answer from among the multiple choices. Some careless mistakes in the calculation lead to the loss of score points. Students sometimes had correct answers in the iRAT, but they might not have fully understood the concepts of the question, since they could not write down the calculation procedures correctly.

TBL was first developed by Michaelsen for large business classes and later applied to health sciences education [1]. For some clinical problems, there is only an optimised answer rather than a standard answer. TBL is an effective method for finding the optimised answer through group discussion. If group members come from different, heterogeneous backgrounds, the effectiveness of brainstorming and discussion is better [1].

On the contrary, the basic concepts of electric circuits are a fundamental science, and have definite clear-cut answers. Does TBL help? From this study, the answer is positively *yes*. TBL can increase the understanding of electrical circuits, and TBL can promote students' self-learning and communication skills. When students pre-viewed by themselves, they could find out the portions they did not understand and discuss these with the group members in the classroom. They also could help other group members, if they already understood the material. It would be a good opportunity to learn how to cooperate with other people. This result supports O'Connell's finding [13].

O'Connell applied TBL in a sophomore-level basic electric circuit theory sequence [13]. Students not only understood the course better than the traditional lecture-based setting, but also developed some transferable professional skills. It was demonstrated that learning how to behave in a group earlier would be helpful in attending the senior courses with strong team skills. Therefore, it is advantageous and encouraging for TBL to be performed in an electric circuit course for students in their freshman year.

In order to promote academic performance and team-work skills, TBL can make the learning more enjoyable [14][15]. Lots of students laughed out loud during group discussions. Students felt very excited when they scratched the correct answer, especially, when they had the right answers sequentially. The results of the survey also show that students enjoyed team time and loved discussions with other team members.

In this study, the performance of the second TBL was better than in the first TBL. Being familiar with the team partners and TBL procedures was helpful for improving the academic performance. Students need to spend time preparing the class materials before class, so teachers need to consider the students' workloads to decide how many periods of TBL should be performed in a course. According to the survey, students spend an average of 2.74 hours in each TBL for pre-reading. It seems the workload was not too heavy. Increasing TBL periods in the future electric circuit course seems acceptable.

AC circuits are more difficult than DC circuits for students to understand. TBL can promote learning effectiveness and retention [16][17]. Furthermore, understanding basic concepts and having critical thinking are essential skills for troubleshooting electrical circuits. Therefore, electrical circuits troubleshooting would be a good topic for application in TBL.

CONCLUSION

Team based learning is an effective teaching strategy for applying in an electric circuits course. After learning about DC circuits, AC circuits and troubleshooting circuits could be good topics for learning in TBL.

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