Abstract

Team-Based Learning (TBL) is an evidence-based collaborative learning teaching strategy designed around units of instruction, known as “modules” that are taught in a three-step cycle: preparation, in-class readiness assurance test (RAT), and application-focused exercise. The in-class RAT includes two sub-tests: individual RAT (iRAT) and team RAT (tRAT). In first-year programming classes, the instructors rely on the mini-lecture to deliver advanced concepts or present a programming exercise to the students. Meanwhile, most of the class time is consumed by the iRAT, tRAT, and application-focused exercise. This paper sheds light on an attempt to modify the conventional TBL approach by taking the iRAT outside the classroom and exploit its time to extend the mini-lecture time. This modification is achieved by the aid of an interactive online book, which ensures that the students finished their reading assignments before the class. Hence, the interactive book can allow us to take the iRAT outside the classroom, which will save at least 20% of the class time. The proposed approach was implemented to a class of 165 students in Fall 2019 and 47 students in Spring 2020, and the preliminary results show that the students finish each class reading assignment with an average percentage of 87%.

Keywords: iRAT, Team-based Learning (TBL), Interactive online book

1 INTRODUCTION

Team-Based Learning (TBL) is a relatively new teaching methodology that encompasses the notion of a flipped classroom. A “flipped classroom” is one in which the students are exposed to the materials before the class, and class time is consequently utilized for group work, discussion, and application of those materials. TBL has been implemented over a wide range of disciplines, notably in the medical field, and recently in programming-related disciplines. The implementation of TBL has shown positive effects in the retention rate of students, success in their first-year courses, and success in their overall degree programs [1,2,3,5]. It has also been shown to increase students’ engagement with the material and has received positive feedback from students [7, 10].

The implementation of standard TBL is also slowly evolving, as many instructors are seeking to improve the TBL model by making adaptations to its structure [4,6,8,9]. Some have implemented a TBL format that excludes the individual Readiness Assessment Test (iRAT), and others have integrated mini-lectures into their TBL class time. Some alterations have also been made to the way laboratory work is approached. In this paper, we aim to highlight the results of removing the individual Readiness Assurance Test (iRAT) from the class period while also integrating an interactive online textbook into the course structure.

In first-year programming classes, the lecture time is 50 minutes, which is divided into 10 minutes for the iRAT, 10 minutes for team Readiness Assurance Test (tRAT), 20 minutes for the mini-lecture, and finally 10 minutes for the Application Activity (AA). Since the instructor stresses more on advanced topics during the mini-lecture time, 20 minutes is not enough for delivering the main idea of the advanced topic and demonstrate an example. Also, it will be helpful to the students to extend the AA time by five more minutes to give them the change to discuss and then write their code. We propose modifying the TBL approach so that the iRAT is taken outside the classroom time and exploit its time to extend the mini-lecture time and the AA time.

However, the iRAT is the only way to ensure that the students individually read the assigned readings before the class. Our proposed solution is to use an interactive online book instead of a regular textbook. This online book is designed to give the student grades based on their readings. As an example, the
instructor creates an assignment for the students to read sections one, two, and three from chapter one with the due time of this assignment before the class. The students will read the indicated sections from the online book. Each section has short questions to make sure that the students already read the section’s content. Finally, a grade is assigned to each student based on his/her completeness of the reading assignment.

2 COURSE STRUCTURE AND METHODOLOGY

This course is mainly designed to teach programming to first-year students from computer and software engineering majors. This course is having two lectures per week. Each is 50 minutes, and there is also a two-hour lab once a week. The course is having two main categories of assignments; outside the classroom assignments and in-classroom assignments. The Outside of classwork includes reading and homework on an online interactive textbook as well as the individual reading assurance test (iRAT). The in-classroom classwork is based on the following sequence:

- The students start by completing the iRAT with their permanent teams that get formulated at the beginning of the semester.
- After the students complete the iRAT assignment, the instructor discusses with the teams the challenging iRAT questions.
- After the iRAT, the instructor then has a 20 minutes mini-lecture, which covers the material that the students were assigned reading for from the interactive textbook before class begins, in addition to advanced topics when applicable. The mini-lecture is meant to strengthen and clarify student understanding of the material, not to introduce it.
- After the mini-lecture and a better understanding of the material being covered, students start working on the AA. The AA consists of a harder single problem that requires students to write/modify/correct a full program with their team members.

2.1 Team Formulation

Teams are determined at the beginning of the semester through a survey that takes into account the individual student’s previous programming experience and his/her comfort in a team discussion, including leading a team discussion or speaking loudly to the class. Each response is rated on a scale from one to five, where one is not comfortable/not experienced and five is very comfortable/very experienced. The instructor then uses the survey results to construct the permanent teams. The main priority is to ensure that each group consists of at least one or two students that rated themselves as very experienced (rating of a 4 or 5 on the survey) with coding/programming. The instructor then proceeds to administer students who rated themselves as very comfortable (rating of a 4 or 5 on the survey) to each group. This is done to ensure that there are at least 1-2 students in each group that can lead the team conversation, which is vital for team success. Lastly, the instructor distributes students who rated themselves as inexperienced with programming as well as uncomfortable with leading team discussion (rating of 1-3 on the survey). This process ensures that each group is diverse and has an equal advantage.

2.2 Interactive Online Book

The interactive online book for this course is used by students before every lecture to gain a basic understanding of the topic before going to lecture. The interactive book is set up so that while students are reading a particular section, there are questions after that section that the students answer for a grade. The questions are concise but very helpful in enhancing student understanding. If the student gets the answer to the question wrong three or more times, the book gives the option of revealing the answer. Hence, if a student is struggling with a particular question, s/he is given the answer so that s/he can reflect on it. As well as the readings, the interactive textbook has “challenge activities” added at the end of each section. The challenge activities are assigned as weekly homework for students to complete. These activities are built into the online interactive textbook and are graded automatically. The questions in these activities ask students to complete partially written code, which runs and checks different cases to verify that the students’ work was done correctly. Partial credit is given if some, but not all cases work. Unlike the regular readings, answers are not provided to students if they cannot solve the problem.
2.3 **individual Readiness Assurance Test (iRAT)**

In this course, the iRAT is completed outside of class. Hence saving 20% of the class time. For typical TBL courses, the class starts with the iRAT. The reasoning behind moving the iRAT outside of class is to conserve as much lecture time as possible. When the lecture is only 50 minutes long, the extra 10 minutes that is usually taken up by the iRAT at the beginning of the lecture gives the instructor more time for the mini-lecture and/or gives the students more time to work on the AA at the end of class.

2.4 **Team Readiness Assurance Test (tRAT)**

The tRAT is completed by each team within the first 10-15 minutes of the lecture period. The tRAT consists of the exact same questions as the iRAT, except the questions are answered within the student’s assigned teams. This is done so that students can collaborate on questions that they may have struggled with individually. This offers students learning opportunities for course material as well as communication and team skill improvement. Unlike the iRAT, the tRAT is submitted as a grade. This is done to motivate students to collaborate with peers in order to submit the best work that they can.

2.5 **Application Activity (AA)**

The AA is a reliable tool for helping students communicate, work as a team, as well as learn how to program via practicing. This is due to the AA consisting of one relatively difficult problem where teams have to collaborate and work together to come up with a solution for it. If the iRAT were in class, students would only have ten minutes only to work on this problem at the end of the class. Taking the iRAT outside the classroom will leave more time to be utilized for the AA.

3 **RESULTS**

Results from this study are depicted below in Figs. 1-6. These figures include comparisons between online reading and challenge activity grades, online reading participation, iRAT and tRAT participation, as well as iRAT and tRAT average grades. Figs. 1 and 2 focus on the comparison between the active learning course (Fall 2018) and the TBL course (Fall 2019). Figs. 3-6 focus on the comparison between the Fall 2019 and Spring 2020 semester, which were both taught using TBL approach. The main difference between Fall 2019 and Spring 2020 is that the iRAT became an online practice quiz during the Spring 2020 semester (graded). In the Fall 2019 course, the iRAT is made available to the students to practice with no required submission (ungraded).

Fig. 1 compares the reading scores from the Fall 2018 semester (active learning) and the Fall 2019 semester (TBL). As depicted in the figure, it is noticed that for every topic, the Fall 2019 reading grades are higher than the Fall 2018 reading grades in every category.

![Figure 1. Students' interactive book reading grades](image-url)
This change ranges anywhere from a 2-14 percent increase in reading grades for the Fall 2019 TBL course. This could be attributed to students possibly feeling the need to be more prepared for the lecture because they were required to know the material from the readings for both the iRAT and the tRAT. Motivating them even more to complete the readings, the tRAT scores are included as part of their grade.

Fig. 2 shows a comparison between Fall 2018 and the Fall 2019 reading challenge grades (homework portion). This portion has a lot of fluctuation between both the Fall 2018 and the Fall 2019 semester. This fluctuation is best explained by the challenge activities not being as large of a component in the Team-Based Learning structure as the readings. This is because the challenge activities aren’t required to be completed before each lecture, they are usually assigned to be completed once a week.

![Figure 2. Students’ interactive book homework (challenge) grades.](image)

Fig. 3 is a comparison between the iRAT and tRAT participation during the Spring 2020 semester. As shown in the figure, there is a large decrease in participation after the class #18 tRAT. This is due to the course being moved online during the COVID-19 pandemic. Students were still able to work together as a team online, but answers as to why participation is still so low can be attributed to many factors. One of these factors is a decrease in student motivation. Students signed up for face to face interaction and may not be as adapted to online learning, causing them to not feel as motivated to participate and excel in the course. Another possible factor lies in trouble communicating with team members. Although communication with team members is still possible, it is slightly more difficult, and not all team members are available to complete the tRAT and AA at the same time. It is also noted that during the Spring 2020 semester, class #9 had considerably less participation than the Fall 2019 semester. This is because there was a University engineering career fair going on that day, so many students were unable to complete the RAT’s that day.

![Figure 3. iRAT and tRAT participation based on students’ participation.](image)
Fig. 4 shows the comparison between tRAT and iRAT grades during the same semester. Along with a participation decrease, there is also a slight decrease in average iRAT scores. As shown, class 19 has an average of 73% (the first online lecture), and classes 20 and 23 both have an average below 80%. Every class before that (except class #17) had an average of at least 80%, but most were well above that. The decrease in the average grades on the tRAT for classes 19, 20, and 23 are attributed to the same factors that caused a massive decrease in participation.

Fig. 5 depicts a comparison of tRAT participation between the Fall 2019 semester and the Spring 2020 semester. The participation for both classes is very consistent up until class #19, where the Spring 2020 participation fell drastically. This data is a good indication that the fall in participation is due to the class being transferred online due to COVID-19. Although participation decreased drastically, students who did participate averaged within 10% (+/-) of students who participated in the Fall 2019 tRATs.

Although the averages were lower for class 19 and 23 for the Spring 2020 semester, the average for class 20 was higher despite it being an online course. This data suggests that the students who participated in the online TBL format are just as successful as students who did not take the class online (Fall 2019 semester). Reading participation stayed roughly the same between both the Fall 2019 and the Spring 2020 semester (depicted in Fig. 6). There is a small decrease in participation from class 19, 20, and 23. The decrease in reading participation is still there but not as significant as the decrease in tRAT/iRAT participation. This could be due to the readings and homeworks being put together in the
interactive online textbook, and that in order to complete the homework, students use the readings as a guide.

![Spring 2020 Reading vs Fall 2019 Reading Participation](image_url)

Figure 6. Comparing Students’ participation in online readings.

4 STUDENTS FEEDBACK

At the end of the Fall 2019 semester, a course evaluation was administered by the university. Students saw many positive and negative aspects of the course and shared it with written feedback. One student noted that “the RATs force you to come to class prepared” and another student noted that “The textbook, in particular, was super helpful. Being online, it had the ability to give me in-book questions that involved programming- which is just what I needed to understand the course material better.” These comments suggest that the interactive online textbook, as well as the iRAT outside of class, better prepare students for the tRAT at the beginning of class and the AA at the end of the class, enhancing performance. Some negative feedback was also incorporated into the survey results. One student noted that “[The RATs] had TONS of typos, and small syntax variations make a big difference in code interpretation.” This was a common comment seen by students in the survey. The RAT typos were, for the most part, fixed for the Spring 2020 semester.

Students were also given the opportunity to give written feedback through a course evaluation form administered by the instructor during the lab periods. The surveys asked students to reflect and give a rating on a scale of 1-5 (1 being the worst and 5 being the best) on each RAT (tRAT and iRAT). Students also added comments as to why they rated each activity the way that they did. The survey used during this section is the most up-to-date one, which was administered during the spring 2020 semester.

There was a lot of positive feedback given by students. One student said that the RATs “[encouraged] class participation.” Another student said that the RATs were “helpful in teambuilding and bouncing our learning off one another.” On the whole, students see the iRAT as helpful in building communication skills with team members as well as the technical skills required to do well in the course. In addition to the RATs’ positive feedback, there were also a few critiques. One student stated that “iRATs feel pointless since they aren’t graded.” In order for students to maximize team efficiency and submit the best answers for the iRAT, it is essential for everyone in the group to complete the iRAT before class so that they have time to consider each question before the lecture begins. A possible solution for motivating students to complete each iRAT would be to add bonus points at the end of the semester based on how many iRATs they have completed throughout the semester.

5 CONCLUSIONS

Based on our results and taking into account the transition from in-person to online TBL due to COVID-19, shifting the responsibility of completing the iRAT to the students on their own time does not decrease the effectiveness of TBL and effectively allows time for in-class discussion, group work, and the mini-lecture.
Regarding the interactive textbook, the reading homework grades with the no-iRAT TBL (Fall 2019) even seems to be consistently higher by a small amount throughout the semester and by topic than that of active learning (Fall 2018). The same observation can be made for the interactive textbook challenge activity grades. The scores also fluctuate less with no-iRAT TBL, displaying more consistent student performance than during the active learning delivery of the course. Although the absence of the iRAT in class may not be directly related to these trends, we can say that the absence of iRAT does not hurt the quality of students’ individual preparation and that no-iRAT TBL has a positive impact on student engagement with their interactive textbook throughout the semester.

Nonetheless, according to the student feedback, students seem to experience the same TBL benefits with the iRAT being outside of the class as opposed to during class. Overall, RATs are viewed as beneficial to discuss and take in groups, while AAs are very effective in stimulating students’ critical thinking and application of concepts. The main issue lies in motivating more students to attempt the iRAT. Possible incentives could be to distribute bonus points at the end of the semester based on each students’ number of iRAT attempts or to improve the group sense between team members, motivating them to come more prepared for the groups’ sake. Future implementations of no-iRAT TBL with the interactive textbook will need to encourage more students to attempt the iRAT in order to obtain more explicit results and/or to reap the full benefits of no-iRAT TBL.

ACKNOWLEDGEMENTS

This research was fully funded by the College of Engineering at Iowa State University. We would like to thank Professor Holly Bender, from the University of Arizona who provided insight and expertise that greatly assisted the PI, Mohamed Selim, in the early stage of developing the modified TBL approach, although she may or may not agree with all of the interpretations/conclusions of this paper.

REFERENCES


