MIXED ACTIVE-TRADITIONAL LEARNING VERSUS TEAM-BASED LEARNING: A COMPARATIVE STUDY FOR A FRESHMEN PROGRAMMING COURSE

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Abstract

A comparative study to show the effectiveness of Team-Based Learning (TBL) and Mixed Active-Traditional (MATL) learning for an introductory programming course at Iowa State University is discussed in this paper. The introductory programming C course was offered to 46 students using TBL and 50 students using MATL, led by two different instructors who use the same course schedule and textbook. The students on both courses received the same number of lectures/labs during the semester. To be able to assess the two methodologies, the instructors deliver the same course contents. Still, they differ with the course delivery method. MATL utilizes maximum class time for traditional lectures with class activities, and the TBL utilizes the maximum class time for interactive group activities with mini-lectures. Homework, reading assignments, and the final exam results are compared to check both teaching methods' overall effectiveness. Although students were satisfied with both teaching methods, students' performances were better in TBL than the MATL.

Keywords: Team-Based Learning (TBL), Traditional Learning, Active Learning, Freshmen Programming

1 INTRODUCTION

Team-Based Learning (TBL) is an emerging cooperative teaching methodology that aims to improve student learning. Although TBL is used primarily to increase student understanding of course material, some instructors also use TBL to increase student engagement, satisfaction, professional skills, academic growth, and even program retention. TBL has the potential to achieve this by utilizing student diversity as an advantage to students' overall learning, whether it be by experience, knowledge, background, age, or other factors [1]-[4].

Many promising studies have been done comparing the effectiveness of TBL over traditional lecture-based learning [5]. In recent years, similar comparisons have been made between TBL and a variety of modified teaching methodologies, showing that TBL can increase student success and satisfaction and collaborative skills [6]-[8]. In [7] notably, the authors reflect on the use of TBL to the instructors' advantage on a course with multiple instructors, allowing them to coordinate the curriculum more easily. The studies all show that TBL is beneficial to many aspects of students' learning; however, these studies have been done primarily in healthcare-related fields.

In this paper, we will be comparing the student performance between a Mixed Active-Traditional Learning (MATL) and TBL version of an introductory programming course.

We define the TBL as a non-lecture-based learning style, which instead depends on individual student preparation, permanent student teams, and in-class team activities. As part of individual preparation, the student will learn the materials before class through an interactive textbook followed by an individual Readiness Assessment Test (iRAT). The interactive textbook is available online and has readings and simple questions to check student's understanding. The iRAT is a short five-question quiz that the students will take individually after completing the readings and before class. The iRAT is not graded; however, it is a crucial component of TBL related to the team Readiness Assessment Test (tRAT) [9].

At the start of each TBL class, each group works together to discuss and complete the tRAT, a repeated copy of iRAT questions. The instructor debriefs the class's quiz results and will proceed to have a short mini-lecture that reviews the concepts the students read about for that particular class. As the final in-class activity, the students will again work together to complete the Application Activity (AA). This programming assignment requires students to write, finish, or debug code [10].

On the other hand, we define the MATL style as so because it takes on a traditional lecture-based teaching style and incorporates a class activity at the end of the lecture that includes a tRAT and an AA combined. In the MATL class, students are free to choose between working individually or picking random peers (e.g., 2 or 3 students in one group) to work on the class activity. The MATL class also utilizes the same interactive textbook, but the key differences between MATL and TBL are how class time is utilized, student teams in TBL, completing tRATs and AAs, and the lack of iRATs in MATL. A more detailed explanation of the courses and the TBL components are included in the Courses Structure section.

Two different instructors taught the courses; however, they utilized the same lecture materials, online textbook, final exam, and followed the same schedule to deliver the course. We will be focusing on analyzing the students' performance in homework via the online interactive textbook and the final exam. This study aims to observe the effect of course delivery and methodology on student performance in an introductory programming course. A detailed study of the effect of COVID-19 pandemic on the same course can be found in [11].

2 COURSE STRUCTURE

The two compared courses were designed as an introductory programming course primarily for first-year software and computer engineering students which were delivered during Spring 2020 semester. Before the emergency shift to online course delivery, the two courses were delivered synchronously as follows. Each week, there are two 50-minute lectures and one two-hour lab. There are also weekly assignments in-class and outside of class, outlined for each course delivery methodology in the following subsections.

2.1 Mixed Active-Traditional Learning (MATL)

The class was delivered via two lectures per week, and the in-class activities were organized as follows:

- Lecture 1: A traditional 50 minutes interactive lecture with questions and answers session.
- Lecture 2: The first 20 minutes were used as the traditional interactive lecture time with questions and answers session. The rest of the 30 minutes was utilized as follows to complete the class activity: 1) a 10 minutes quiz followed by an open discussion about the quiz for 5 minutes, and 2) class activity which consists of one programming assignment where the students work in groups to write and submit the assignment within the last 15 minutes of the class.

Table 1 shows the layout of the MATL class.

For the out-of-class activities, there were two main activities; 1) lab (2 hours) where students work individually on a specific lab assignments, and 2) homework.

2.1.1 MATL Team Formulation

Working in a team was not mandatory for the MATL. However, students were suggested to work in a group composed of 2/3 students for the class activity and the final project. In the first class, the students were instructed to discuss each other and form teams that may include 2/3 students.

The good news is that the first team formation was not permanent, and the students had the freedom to switch from one team to another team anytime they want. It was found that the students were happy to switch between teams, and finally, they ended up with an excellent team. It was also found that some students were wanted to work alone for their class activity and the final project due to their work schedule limitations. In short, most of the students in MATL were allowed to work in a random team formulation, and few students were allowed to work alone for their class activity and the final project.

TABLE 1. MATL CLASS LAYOUT.

Item	Face-to-Face	Online
Lecture 1 M: Monday	**Starting:** 10:00am on M **Closing:** 10:50am on M	**Starting:** 10:00am on M **Closing:** 10:50am on M
Lecture 2 W: Wednesday	**Starting:** 10:00am on W **Closing:** 10:20am on W	**Starting:** 10:00am on W **Closing:** 10:20am on W
Class Activity	**Starting:** 10.20am on W **Closing:** 10:50am on W	**Starting:** 10.20am W **Closing:** 10:50am on W

2.1.2 MATL Class Activity

There was one class activity assigned every week except the first and last two weeks of the semester. Each class activity was composed of two different types of questions, where the first type of problem was the same as the tRAT in TBL, and the second type of problem was the same as the AA in TBL. The class activities were not limited to the teamwork, and the students were allowed to work alone if they want. The students were suggested to complete the class activity within the class time, but they were allowed to submit the class activity before the next class for the evaluation. For any questions regarding the class activities or lectures, the students were suggested to use the discussion section on Canvas, where the instructor or TAs answers the student's questions.

2.2 Team-Based Learning (TBL)

The class was delivered via two lectures per week, and the in-class activities were organized as follows:

- tRAT (10 min)
- RAT Discussion (5 min)
- Mini-lecture (20 min)
- AA (15 min)

For the out-of-class activities, there were three main activities as follows:

- Lab (2 hours)
- Homework (interactive textbook)
- iRAT (max. 30 min)

Table 2 shows the layout of the TBL class.

2.2.1 TBL Team Formulation

Teams are determined at the beginning of the semester (the second week since the first week the number of students is always dynamic due to the drop/add flexible policy) through a survey that considers the individual student's previous programming experience and comfort in leading a team discussion. Each response is rated on a scale from 1-5, where 1 denotes not comfortable or not experienced, and 5 denotes very comfortable or very experienced, respectively. Teams are constructed based on the survey results by the instructor. The main priority is to ensure that each group has at least one student comfortable with programming and at least one student who is comfortable in a team discussion. It is worth pointing out that the formulated teams are final with minor changes after the course instructor approval.

The rest of the students are distributed similarly. By spreading students in this manner, there will ideally be one or two students who will lead group discussions, one of the main factors for team success. Ultimately, the goal is to have equally advantaged and disadvantaged teams.

TABLE 2. TBL CLASS LAYOUT.

Item	Face-to-Face	Online
iRAT	**Starting:** 5pm on M/W **Closing:** 3:10pm on T/TH	**Starting:** 9am M/W **Closing:** 3pm on M/W
tRAT	**Starting:** 3:10pm on T/TH **Closing:** 3:20pm on T/TH	**Starting:** 3pm M/W **Closing:** 3pm on T/TH
RAT Discussion and Mini-lecture	**Starting:** 3:20pm on T/TH **Closing:** 3:45pm on T/TH	**Starting:** 3pm on T/TH *RAT discussion Posted as videos and Mini-lecture delivered live and recorded*
AA	**Starting:** 3:45pm on T/TH **Closing:** 4:00pm on T/TH	**Starting:** 3:10pm on T/TH **Closing:** 11:59pm on T/TH

2.2.2 TBL Class Activity

There are different class activities implemented in the TBL class. How these activities are delivered is presented below:

- **iRAT**: The iRAT for this course is completed before class to save as much class time as possible. 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 10-15 minutes usually taken up by the iRAT at the beginning of the lecture gives students more time to work on the AA at the end of class. The AA is a robust tool for helping students communicate, work as a team, and learn to program. If the iRAT were in class, students would only have a couple of minutes to work on this problem at the end of the class. Taking the iRAT outside of class gives students a better opportunity to collaborate with their team and submit the right solution for the AA.
- **tRAT**: Each team completes the tRAT within the first 10-15 minutes of the lecture period. The tRAT consists of the 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 their teammates.

- **AA:** Each class also has an associated AA that is completed at the end of the class period. Like the tRAT, the AA is completed as teams. The AA is a more involved problem-solving assignment than the homework problems in the online interactive textbook or the RAT questions. Its focus is on writing code. The AA will typically outline a problem and ask the students to write a complete program or finish an incomplete program to produce a given output.

3 SIMILARITIES BETWEEN MATL AND TBL

Both courses followed the same schedule over the semester. Besides, the courses' instructor used the same textbook, allowing them to assign the students from the two courses the same reading and homework assignments. In addition, the students from both classes had the same final exam.

3.1 Interactive Textbook

Students use the online interactive textbook for this course before every lecture as preparation for that particular class's topics. The online interactive textbook includes reading sections, each of which features multiple pre-class reading questions and a few homework questions. One of the benefits of utilizing an online interactive textbook is that students always have immediate access to their pre-class reading and homework assignments.

Fig. 1 displays examples of pre-class reading questions that are answered correctly and incorrectly. The first question has been answered correctly, as denoted by the green box, supplemental explanation, and orange checkmark flag on the right. The student will receive points for this question. The second question has been answered incorrectly, as denoted by the red box with a hint inside. The flag to the right remains unchecked, and the student will not receive points for this question until it is answered correctly, or they choose to display the answer. The textbook will give an option to display the answer if the student answers incorrectly three or more times. Since an explanation of the correct answer is given, the student can still receive points if they display the answer after answering incorrectly. All reading questions must be completed before each class.

Likewise, the online interactive textbook includes homework problems. These problems typically ask students to finish a given code to produce the specified output. Unlike pre-class reading questions, if the student does not enter a correct solution, the student will not get full credit.

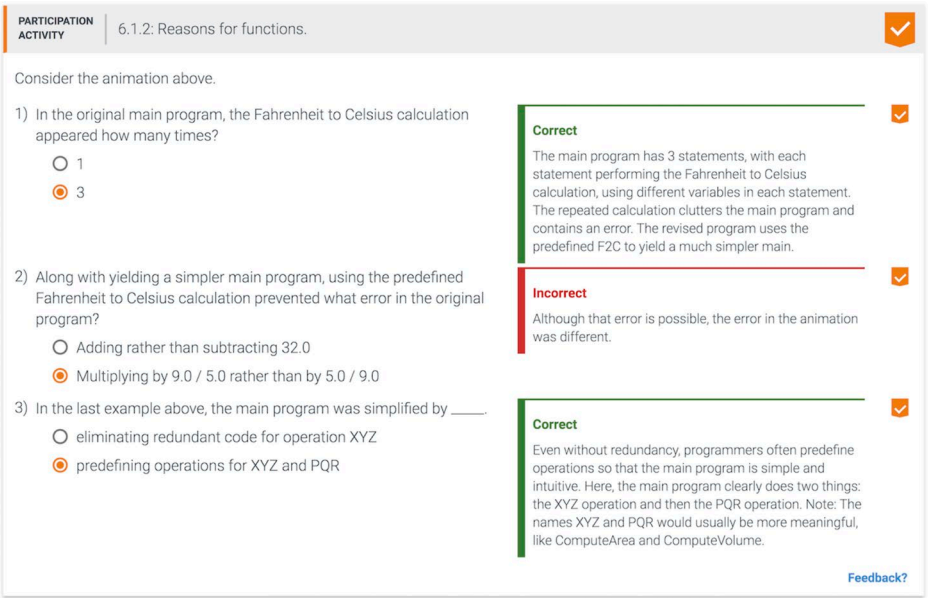

Figure 1. Sample online interactive textbook reading questions.

Partial credit is possible, however, if the student's code works for some cases, but not all cases. In Fig. 2, a sample homework question that has been answered correctly can be seen. Two blue flags to the right have been filled and checkmark indicating that the student's code passed one case and all cases, respectively. Additionally, the homework questions do not have to be completed before the class period. Students have until the end of the week to complete homework questions.

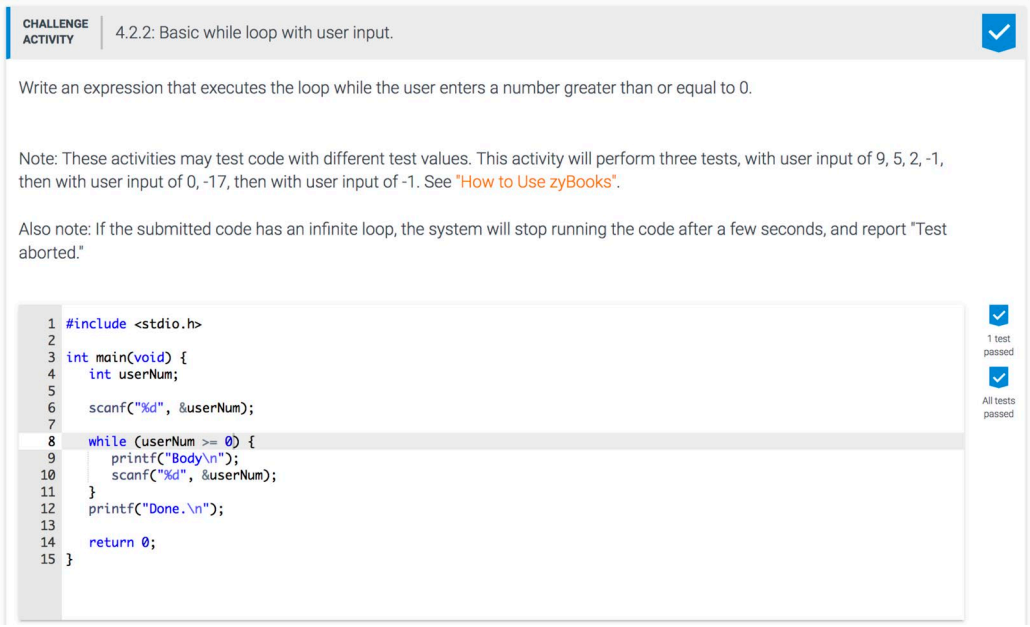

Figure 2. Sample online interactive textbook challenge questions answered correctly.

3.2 Final Exam Common Format

The exams were both delivered online via Canvas Lockdown Browser. Lockdown Browser is a browser that prevents cheating during online tests. While using the Lockdown Browser, students cannot access other websites, print, or copy while taking the exam. However, the exam was open-note.

The exam was 16 questions long; however, we compared only 14 questions. Out of the two questions omitted from comparison, the first question was a free question that was only worth one point. The other question was a files-related question that differed between the MATL and TBL class, worth 16 points. In Total, the final exam was worth 115 points but was taken out of 100. We compared 98 worth of points. Also, note that the exam graders were the same between the MATL and TBL classes.

4 ANALYTICAL RESULTS

The final exam and homework data from the MATL and TBL classes were compared and decomposed to see if there were any clear differences between the two courses. The data comprised of 50 MATL students and 46 TBL students.

Fig. 3 displays the final exam results by exam questions for both the MATL and TBL courses. The scores for the TBL class are consistently higher than the MATL class, except question 14, the bonus question. Question 4 was a true/false question asking whether a recursive function with infinite calls or an infinite loop would require more memory. The topics of infinite loops and recursion were both covered in depth; however, the comparison of memory consumption may not have been explicitly covered, explaining the overall low scores for this question. As for the higher MATL averages for question 14, the bonus question, a possible explanation is that more students may have attempted it to make up for points lost in other questions of the exam.

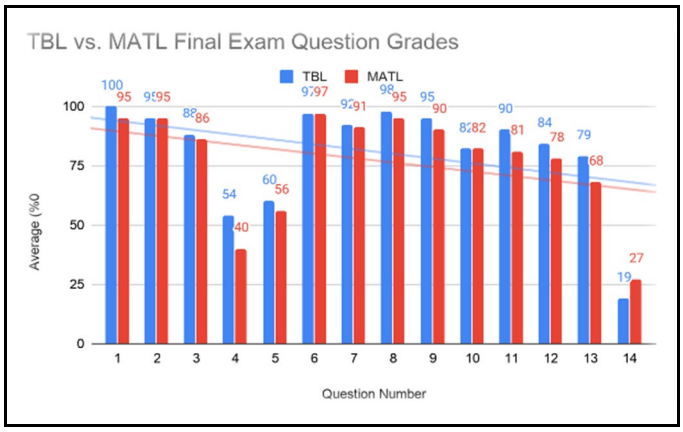

Figure 3. Comparing final exam averages between Spring 2020 TBL and MATL courses.

Fig. 4 and 5 compare data from the online interactive textbook of the TBL and MATL classes. As explained in the Courses Structure section, the interactive textbook consists of pre-class reading questions and homework questions. Fig. 4 compares the reading questions, while Fig. 5 compares the homework questions.

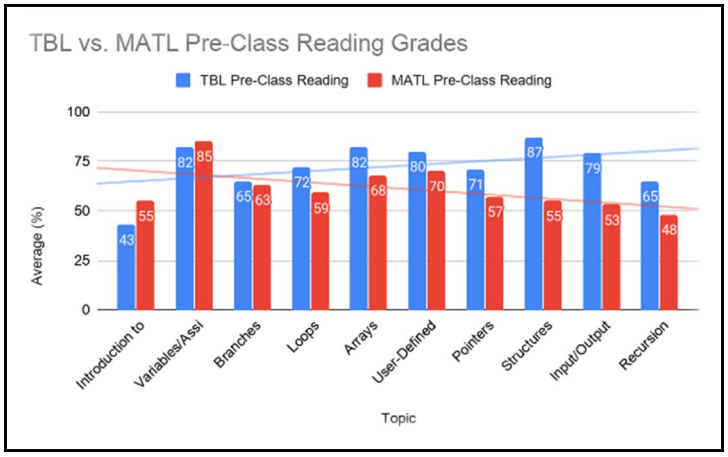

Figure 4. Comparison of reading grades by topic of the Spring 2020 TBL and MATL courses.

From Fig. 4, we see that the TBL reading grades have a higher trendline, which may indicate more consistent participation and increased learning throughout the semester in comparison to MATL. Although both TBL and MATL's readings were due before class, this can be explained by the fact that TBL students may have felt more enforced to read and complete reading questions before class to better complete the iRAT and tRAT. Additionally, the lower averages for TBL in the first two topics are most likely due to the readings being optional for the first week, i.e., not graded. A possible explanation for the discrepancy between the first and second topics of TBL reading grades is that fewer students may have purchased their textbooks in the first week. Students may have also felt inclined to start completing their readings to prevent losing points in their tRATs and AAs as they may have in the first week.

In Fig. 5, although TBL shows slightly higher averages for homework grades, there is little difference between the TBL and MATL classes. This similarity may be explained by the fact that for both TBL and MATL, students had the option to complete homework after class.

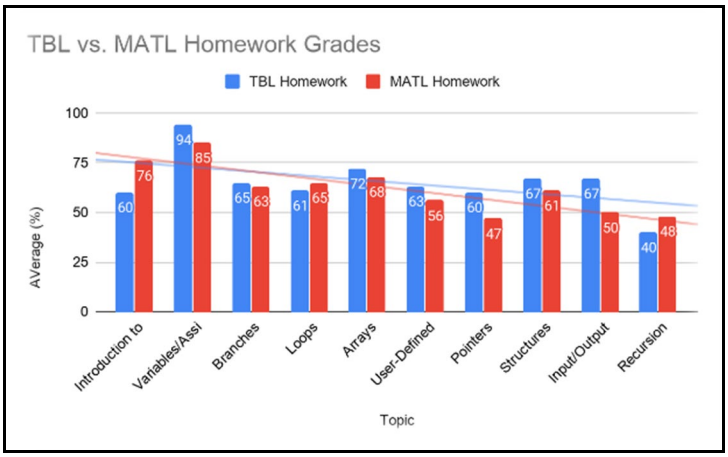

Figure 5. Comparing homework grades by topic of Spring 2020 TBL and MATL courses.

5 CONCLUSION

Implementing a TBL and MATL version of the introductory programming course allowed us to analyze the effectiveness of group-based learning activities. It appears that the TBL delivery of the course has potential in better engaging students throughout the course and improving their overall learning outcomes. Using the iRAT and tRAT as an indirect incentive to gauge students' pre-class readings appeared very effective throughout the course. Additionally, the question-by-question analysis of the final exam averages between TBL and MATL suggests that utilizing class time for discussion, group-work, and in-class activities may be beneficial for the students' engagement and understanding of topics throughout the course.

Future work can be done on the MATL delivery by introducing a RAT either before the MATL class or at the start of the class. This adaptation to MATL can help us see if this component improves MATL pre-class reading, homework, and final grades. It can also give insight as to how vital the RAT is as a component of TBL as well as help ease traditional, active, or MATL courses into a TBL format.

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