

Transforming a TBL Programming Class from Face-to-Face to Online Due to the COVID-19 Pandemic

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Abstract— The coronavirus disease (COVID-19) is a public health emergency of international concern. The spread of the virus all over the world sent billions of people into lockdown. In light of rising concerns, a growing number of universities across the globe and specifically in the United States have either postponed or canceled all campus events such as workshops, conferences, sports, and other activities. Universities took intensive measures to prevent and protect all students, faculty, and staff members from the highly infectious disease. This resulted in migrating all face-to-face courses into an online course. In this paper, the authors present the impact of COVID-19 on migrating a Team-based Learning C programming course from face-to-face to online delivery and its effect on student learning. The results section of this paper shows that the student learning curve was affected significantly by the sudden online delivery of the course.

Keywords—COVID-19 pandemic, team-based learning, face-to-face, online teaching

I. INTRODUCTION

The coronavirus disease (COVID-19) was recently acknowledged as a global pandemic and posed many challenges not only to physiological and psychological health but also within educational spheres. As a result of COVID-19, universities widespread closed their facilities and shifted to online instructions. This public health emergency induced shift is called emergency remote teaching (ERT). This shift calls for instructors to abruptly adjust the way they teach, oftentimes learning how to use new applications, and calls for students to adapt the way they learn and manage their time and motivation. It is important to note that courses designed and planned to be delivered online differ significantly from courses delivered through ERT, and the quality of delivery and student learning may be compromised [1], [2]. From a university standpoint, there are challenges in shifting from face-to-face (f2f) to online classes, assessing and evaluating students, international students, mental health, and university support services. Discrepancies between students' time zones, access to the internet, major requirements, and other factors all create challenges in shifting to online instructions. However, an assessment of ERT's effectiveness is not a direct comparison to f2f teaching [3]-[6].

Studies have already shown the adverse effects that the COVID-19 outbreak is having on people of all ages, both physiologically and psychologically. Among the general population in China, people reported moderate impacts on psychological health and severe depressive symptoms, as well as other physical symptoms and higher stress and anxiety levels. It seems that the epidemic has instilled a sense of uncertainty and fear and also has disrupted the lives of people all around the world, all of which have had adverse effects on peoples' mental health across the globe. Peoples'

physiological and psychological changes during this time are not only a concern in and of themselves, but they will also impact the quality of learning given and received [5], [6].

Nonetheless, we must look at the challenges of ERT from the perspective of the educator, the content presented, and the student. It is up to the educators to creatively utilize the necessary technology and educational platforms and software to deliver content effectively and up to students' to make use of their self-efficacy. Educators and institutions will also need to provide the necessary support, whether it be technical, resource-related, or emotional. Everyone will also need to employ strong communication skills [2].

In addition, studies reveal that high participation from both sides will be necessary to achieve success in ERT. In this respect, we are interested in observing the effects of ERT due to COVID-19 on a Team-Based Learning (TBL) programming course [7]-[9].

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 pre-class readings and/or videos where this quiz can be graded or no [10]. The same quiz is given to students but this time to work on it as a team during class time and this what we call team Readiness Assessment Test (tRAT). 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 main concepts and advanced topics. 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 [11].

Since the course was originally delivered f2f and given the nature of TBL, the course is assumed to be highly dependent on participation from both the students and the instructor as well as collaboration among student teams. In this paper, we first lay out the TBL course structure along with the adaptations we made to compensate for ERT and the challenges that accompanied ERT. We then go on to observe changes in student engagement and performance throughout the semester and compare exam grades between ERT and a f2f semester. Finally, we conclude the paper by summarizing the results and our findings.

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II. COURSE STRUCTURE

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 I shows the layout of the TBL class.

TABLE I. 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 & Mini-lecture	Starting 3:20pm on T/TH Ending 3:45pm on T/TH	Starting 3pm on T/TH <i>RAT discussion Posted as videos Mini-lecture delivered live and as a recorded video</i>
Application Activity	Starting 3:45pm on T/TH Closing 4:00pm on T/TH	Starting 3:10pm on T/TH Closing 11:59pm on T/TH

A. 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 indicates 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's approval.

B. TBL Class Activity

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

- iRAT: The iRAT (individual Readiness Assurance test) for this course is completed outside of class. This is done to try and 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. This is due to the AA consisting of one challenging problem where teams have to collaborate and work together to develop a solution. 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 (team readiness assurance test) 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 Application Activity (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.

C. 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.



Fig. 1. Screenshot of sample online interactive textbook reading questions with one answered correctly, and one answered incorrectly.

Likewise, the online interactive textbook includes homework problems. These questions 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 answer will not be revealed to the student, and the student will not get full credit.

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.

III. ADAPTATIONS/CHALLENGES

Given that this course is having two lectures per week, there are 30 classes per semester. Out of the 30 total lectures, the first 18 were face-to-face. Following the emergency shift to online course delivery, the remaining 11 lectures were delivered asynchronously as follows:

All in-class assignments were made available online via the same learning management platform, which was being utilized before the emergency shift. However, the time windows during which they were made available were adjusted to adapt to the emergency situation.

The iRAT, tRAT, and AA were no longer included in the original class time structure, as differences in time zone and communication amongst team members needed to be accounted. Consequently, each in-class activity was made available for submission for the time frames shown in Table II. The RAT discussion videos and mini-lecture videos were pre-recorded as separate videos by the instructor and posted at certain times each week. For the whole lecture duration (3pm - 4pm), the instructor was available live via Zoom to answer any questions from students in addition to delivering a mini-lecture and going over the RAT questions to extend

the discussion with the students who already watched the tRAT video.

Labs also had to be changed accordingly. Labs were completed using specific hardware provided by the department before the class was immigrated online due to the COVID-19 pandemic. Since not all students had access to the hardware needed to complete labs, the labs were altered so that they could be completed without a hardware component, while still covering the same topics being taught in the

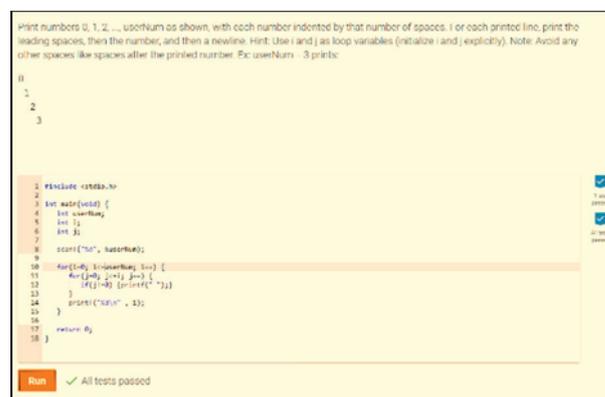


Fig. 2. Screenshot of sample online interactive textbook challenge questions answered correctly.

Course. Also, the instructor replaced one of the labs with a COVID-19 lab where the students are going to program a kiosk to ask hospital patients some questions to identify if they have possible COVID-19 patients based on the centers for disease control and prevention recommendations <https://www.cdc.gov/>. In addition, the students have to guide the patients for the next step (either to proceed to the check-in desk of the hospital or to wait in a designated area until COVID-19 crew are ready to hospitalize them).

Note that there were no changes to homework assignments and their corresponding deadlines. As the nature of a TBL course relies on face-to-face interaction among group members, the most significant challenge of ERT for this TBL course was retaining student engagement and attendance especially for team-based activities such as tRAT and AA. The results are expanded upon in the next section as we observe how student engagement with the new transformation impacted overall student performance.

IV. NUMERICAL RESULTS

The Data was collected from both Fall 2019 semester and Spring 2020 semester. The Fall 2019 semester had the same instructor as the Spring 2020 semester course but was purely face-to-face. A comparison was made between the reading participation, tRAT/iRAT participation, midterm 2 grades, and the final exam grades (midterm number 1 was not included since the two exams were different). It is worth pointing out that not all classes are included in these comparisons. Classes #1-#4, #13-#16, #21-#22, and #25-#26 all either didn't have graded activities or didn't have any activities at all (iRAT, tRAT, AA). Class #24 is also not included in these comparisons because there were errors in the tRAT; hence, it may give wrong results. It is also noted

that although online classes started on class #19, class #9 was also delivered online due to a university-wide engineering career fair that was held during the time of the lecture. As a result, many students could not attend, so the instructor put the material online in a similar format as when it was delivered during the online portion of the course.

TABLE II. FACE2FACE AND ONLINE CLASS CONFIGURATION

Item	Face-to-Face	Online
iRAT	Starting 5pm on M/W	Starting 9am M/W
	Closing 3:10pm on T/TH	Closing 3pm on M/W
tRAT	Starting 3:10pm on T/TH	Starting 3pm M/W
	Closing 3:20pm on T/TH	Closing 3pm on T/TH
RAT Discussion & Mini-lecture	Starting 3:20pm on T/TH	Starting 3pm on T/TH
	Ending 3:45pm on T/TH	<i>Posted as videos</i>
AA	Starting 3:45pm on T/TH	Starting 3:10pm on T/TH
	Closing 4:00pm on T/TH	Closing 11:59pm on T/TH

The most challenging part of the transition between this TBL face-to-face course to an online course was retaining student attention. Reading participation, iRAT participation, and tRAT participation plummeted once online classes began. Fig. 3 shows the comparison of reading participation between the Fall 2019 semester (face-to-face the whole semester) and the Spring 2020 semester (partially face-to-face and partially online). The Spring 2020 course was face-to-face until class number 19. As exhibited, reading scores dropped slightly after migrating online.

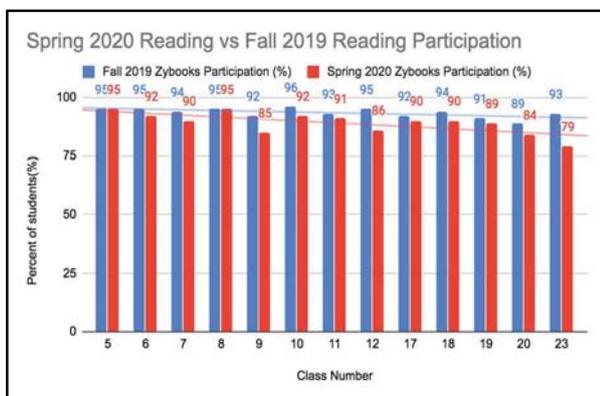


Fig. 3. Comparison between reading activity participation of Spring 2020 and Fall 2019 semesters.

Fig. 4 represents the iRAT and tRAT participation during the Spring 2020 semester. As shown, tRAT participation and iRAT participation drastically decreased, starting at class number 19 (from the range of 60%-91% to 13% and below for the iRAT and from 70%-100% to 53% and below for the tRAT). This significant decrease is also depicted during class number 9 due to the university-wide career fair, where the lecture material was delivered online very similar to the format the material was provided once the course went entirely online. There are a couple of possible explanations for why this happened. For the tRAT, the students struggled, and it was challenging to communicate with their team members online after the pandemic.

Once the university opted to continue the rest of the semester through online courses, most students moved back home. This creates a visible communication wall if team members live across the globe with different time zones. Since the tRAT was made available for 24 hours, students who have an 8-hour time zone difference may have a smaller window of opportunity to communicate and solve the problems.

Another explanation that also explains why iRAT participation dropped to near 0 is that students were unable to stay engaged with the course. Students signed up to take a face-to-face course that involves working with team members. This is most easily done in a face-to-face environment. This being the case, if students are not willing to complete the tRAT, they are even less likely to complete the iRAT since it is individual practice for the tRAT, as well as ungraded. This is shown in Fig. 4 when iRAT participation dropped to 2% for the first online lecture and continued to be less than 15% for the remaining lectures.

Fig. 5 compares the tRAT responses of the students for Fall 2019 and Spring 2020. As it was shown in Fig. 4, the students' participation during the emergency migration is lower than that of the students took the same class with the same assignments back during Fall 2019.

The last two comparisons shown was comparing midterm 2 and the final exam from the Fall 2019 semester and the Spring 2020 semester, as depicted in Fig. 6, and Fig. 7, respectively. Data for these graphs were combined into the letter grade categories of A, B, C, D, and F (where A and A- are combined as A; B+, B, and B- are combined as B; etc.). Surprisingly, the exam scores from the online portion of the Spring 2020 course were slightly better than from the Fall 2019 course.

As shown in Fig. 6, 60% of students received an A on the midterm #2 exam in the Spring 2020 semester, while 51% of students received an A on the midterm #2 exam in the Fall 2019 semester. This trend is also shown in Fig. 7 for the final exam, 33% of students received an A during the Spring 2020 semester, while 20% of students received an A during the Fall 2019 semester. There are a couple of explanations for why this is. The first one being that the exam was not properly proctored the way that they were in the Fall 2019 semester. During the Fall 2019 semester, each exam had 2 to 3 teaching assistants that walked around the classroom during the exam as proctors.

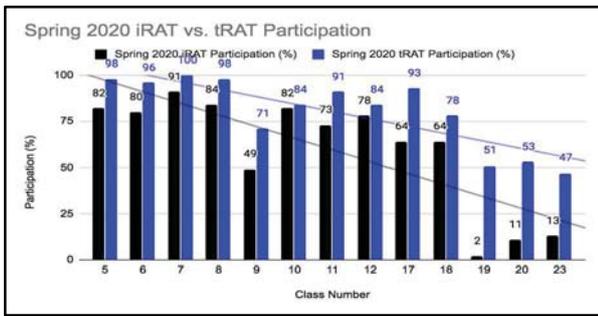


Fig. 4. Comparison between the Spring 2020 semester's iRAT and tRAT participation.

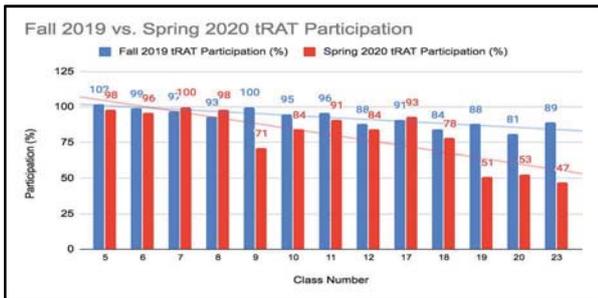


Fig. 5. Comparison between tRAT participation of the Fall 2019 and Spring 2020 semesters.

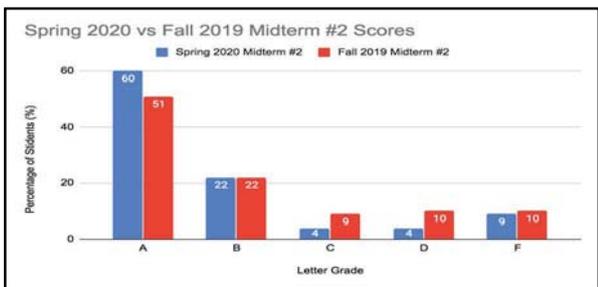


Fig. 6. Comparison of midterm 2 scores between the Spring 2020 and Fall 2019 semesters.

For the Spring 2020 exam, this could not be done due to the exams being online. Instead, students were required to use a lockdown browser while taking the exam. This makes it so that students cannot do any other activity on their computer/personal device while taking the online exam. The instructor was unable to force the students to use a webcam during the exam for proctoring purposes since it was not in the syllabus. Another possible explanation for the difference in exam scores is the difference in sample size. During the Fall 2019 semester, there were 165 students in the course, and during the Fall 2020 semester, there were only 47 students in the course. Overall, there were over three times the amount of students enrolled in the course during the Fall 2019 semester when compared with the Spring 2020 semester.

V. CONCLUSION

After observing student participation and performance over the semester, we can see that COVID-19 proved to be an immediate impediment to student engagement in the course. Within the semester, iRAT participation was affected the greatest, followed by tRAT participation. A conclusion can't be drawn from the difference in test scores due to a couple of factors, these being a significant mismatch in student body size as well as proctoring differences.

By nature, TBL is a methodology that is highly dependent on student engagement, not only with the instructor and course material but between team members. Since the emergency shift to online delivery places significant limitations on inter-student participation, it is evident that TBL does heavily rely on face-to-face interaction and that class in a physical environment is valuable to student engagement and performance in a TBL class. Meanwhile, if the course is

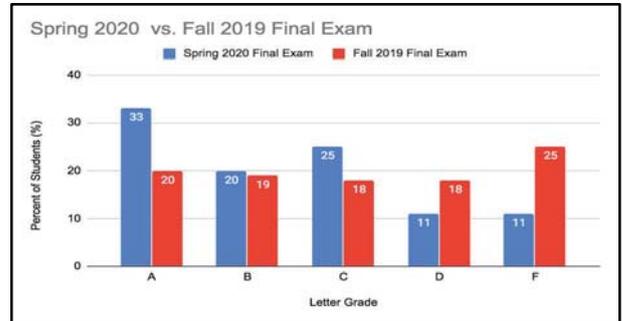


Fig. 7. Comparison of final exam letter grades between the Spring 2020 and Fall 2019 semesters.

designed to be delivered online using TBL, it will not be affected by the pandemic since the students will get used to the course structure. Another remark is that the course instructor must be flexible to accommodate the sudden change of the student learning environment. A syllabus policy change is suggested to enforce students' attendance to ensure students' participation.

REFERENCES

- [1] M. Murphy, "COVID-19 and emergency eLearning: Consequences of the securitization of higher education for post-pandemic pedagogy," *Contemporary Security Policy*, 2020.
- [2] C. Hodges, et. al., "The Difference Between Emergency Remote Teaching and Online Learning," available "<https://er.educause.edu/>".
- [3] P. Sahu, "Closure of Universities Due to Coronavirus Disease 2019 (COVID-19): Impact on Education and Mental Health of Students and Academic Staff," *Cureus*, vol. 12, no. 4, 2020.
- [4] C. Wang, et. al., "Immediate Psychological Responses and Associated Factors during the Initial Stage of the 2019 Coronavirus Disease Epidemic among the General Population in China," *Int. J. Environ. Res. Public Health*, vol. 17, no. 5, 2020.
- [5] J. Crawford, K. Butler-Henderson, J. Rudolph, M. Glowatz, et al, "COVID-19: 20 Countries' Higher Education Intra-Period Digital Pedagogy Responses," *Journal of Applied Teaching and Learning (JALT)*, vol. 3, no. 1, 2020.
- [6] M. Cornock, "Scaling up online learning during the coronavirus (Covid-19) pandemic", available at "<https://mattcornock.co.uk/>".
- [7] W. Bao, "COVID-19 and online teaching in higher education: A case study of Peking University," *Human Behavior and Emerging Technologies*, vol. 2, no. 2, 2020. doi: 10.1002.
- [8] H. Abdulrahim, F. Mabrouk, "COVID-19 and the Digital Transformation of Saudi Higher Education," *Asian Journal of Distance Education*, vol. 15 no. 1, 2020.
- [9] Jumat, Muhammad Raihan et al. "From Trial to Implementation, Bringing Team-Based Learning Online-Duke-NUS Medical School's Response to the COVID-19 Pandemic." *Medical science educator*, 1-6. 4 Aug. 2020.
- [10] J. Lai, C. Kesterson, Mohamed Y. Selim, "An Emergency Transformation of a TBL Programming Class from Face-to-Face to Online Due to The COVID-19 Pandemic", *IEEE TALE*, Takamatsu, Japan, Dec. 2020.
- [11] H. Loftsson and Á. Matthíasdóttir, "Using Flipped Classroom and Team-Based Learning in a First-Semester Programming Course: An Experience Report," *2019 IEEE International Conference on Engineering, Technology and Education (TALE)*, Yogyakarta, Indonesia, 2019.