# ARTICLE
# Comparing Student Performance in Emergency Remote and Face-to-Face Collaborative Learning Courses

**Yasmin Azizi[1], John Hession[2], and Thomas M. Newpher[1,3]***
Department of Psychology and Neuroscience, Duke University[1], Department of Computer Science, Duke University[2], Duke Institute for Brain Sciences, Duke University[3], Durham, NC 27708.
https://doi.org/10.5939/JVIC5712

The start of the COVID-19 pandemic forced an unprecedented shift from face-to-face (F2F) instruction to emergency remote teaching (ERT) for over one billion learners worldwide. Studies from K-12 and higher education have begun to address the impact of ERT on student learning and well-being. The lessons learned from ERT will likely shape the response to future public health emergencies and inform the design and implementation of remote courses. As such, it will be important to identify teaching practices in ERT that promoted student engagement and learning. Here, we address whether undergraduate collaborative learning courses were able to support student content knowledge outcomes at similar levels in ERT as compared to F2F classroom environments. Specifically, we tracked student performance in three different team-based undergraduate neuroscience courses. These courses were all taught by the same instructor during the academic years 2020-2021 and 2021-2022. Importantly, we found that student scores on individual and team assessments as well as measures of course satisfaction were similar between ERT and F2F. Taken together, our data suggest that the virtual collaborative learning environment in these courses was not associated with a decrease in student or team performance when compared to a traditional F2F classroom.

*Key words: collaborative learning; emergency remote teaching (ERT); undergraduate neuroscience; active learning; pandemic*

At the beginning of the COVID-19 pandemic, physical-distancing measures and school closures occurred at a scale never before seen in the modern era. Disruptions to traditional face-to-face (F2F) teaching impacted an estimated 1.6 billion learners worldwide (UNESCO, 2021), and the rapid shift to emergency remote teaching (ERT) presented many challenges for educators and students at all levels of education. ERT, defined as a temporary shift to remote course delivery due to a crisis (Fuchs, 2022; Hodges et al., 2020), often lacks resources and comprehensive faculty support, and is not meant to be a permanent instructional delivery method (Fuchs, 2022; Hodges et al., 2020).

The impacts that school closures and ERT had on student learning are becoming better understood. In K-12 education, ERT was considered a failure (Leonhardt, 2022). Results from a US-based test that collected data from 2.1 million students revealed that the more time students spent at home in ERT the lower their math and reading scores were (Goldhaber et al., 2022). In higher education, however, the results with ERT were mixed. College students surveyed in 2020-2021 reported concerns over social isolation, staying motivated, declining mental health, academic distress and exhaustion, access to high-speed internet, receiving adequate instruction from professors, providing care to siblings, and finding a quiet environment for online learning (Brown, 2021; Hiler et al., 2021; Lee et al., 2021; Lemay et al., 2021). Despite the obstacles to learning associated with ERT in higher education, the results from initial studies focusing on student performance during ERT vary between studies. Decreases in student performance with ERT have been reported (Nazempour et al., 2022), yet other studies have observed no difference (AbdelSalam et al., 2021; Al-Zohbi et al., 2022; Blondeel et al., 2021; El Said, 2021; Engelhardt et al., 2021) or reported that ERT scores increased relative to pre-pandemic averages (Al-Zohbi et al., 2022; Elzainy et al., 2020; Iglesias-Pradas et al., 2021; McMurtrie, 2021). While academic dishonesty and/or relaxed grading policies may have contributed to the score increases, some studies suggested that learners were spending a greater amount of time studying and less time socializing during ERT (McMurtrie, 2021). Instructors also reported reaching out to struggling students more often, creating clearer expectations, and placing greater focus on equitable and inclusive course design (Fox et al., 2021). Indeed, one study found that increased emotional and academic support from faculty during ERT was correlated with higher academic performance in students (Abdullah et al., 2022). Lastly, for students with disabilities, wide-spread use of web-based video lectures brought high-quality recordings of class lectures along with auto-generated closed-captioning (Puang, 2021), vital resources that were often difficult to obtain pre-pandemic. Taken together, these initial findings indicate that college students were stressed and generally dissatisfied with many aspects of ERT. Increased time studying, however, as well as the adoption of new learning tools and improvements to teaching practices may have helped to maintain student learning outcomes equal to or above pre-pandemic levels.

Whether ERT or conventional distance teaching, online course delivery is a flexible space that has the potential to

better serve the needs of learners through lower costs and greater convenience (Peacock et al., 2020). Furthermore, the online format does not appear to negatively impact student learning, as meta-analyses have shown that student performance in online courses can be equal to or above F2F courses (Bernard et al., 2004; Jahng et al., 2007; Means et al., 2013). Despite their convenience, however, online courses can create a less engaging learning environment that suffers from high attrition rates (Carr, 2000; Maimaiti et al., 2021; Peacock et al., 2020). To ensure greater student retention, motivation, and success, it is critical to develop a nurturing online community where students feel a strong social presence (Mitchell et al., 2021; Peacock et al., 2020).

A well-established method to increase social presence and learning in the classroom is to use active, collaborative learning (Bonwell and Eison, 1991; Johnson and Johnson, 1999; Springer et al., 1999; Tanner, 2013). One popular form of collaborative learning is the highly structured team-based learning (TBL) (Michaelsen et al., 2004; Michaelsen and Sweet, 2008). In traditional, face-to-face TBL, students are placed into large and diverse permanent teams. Each TBL module follows a sequence of activities that integrates individual assignments, application-based group work, and timely feedback (Michaelsen et al., 2004; Michaelsen and Sweet, 2008). Importantly, TBL can increase content knowledge outcomes when compared to lecture-based course versions (Swanson et al., 2019). In addition, collaborative approaches like TBL can be easily adapted for remote asynchronous or synchronous formats (Clark et al., 2021; Li et al., 2021; Malik and Malik, 2022; Palsole and Awalt, 2008; Takizawa et al., 2021). In synchronous remote collaborative learning, typical in-person activities can be run through web-based video conferencing software during regular class time. In asynchronous remote collaborative learning, there is no scheduled or synchronous class meeting time and teammates agree on a time to meet for remote collaborative activities (Clark et al., 2021; Palsole and Awalt, 2008).

How well students in collaborative learning courses perform in an online space is a topic of ongoing investigation. Given the unique challenges associated with a distance learning environment, the effectiveness of remote collaborative learning may be reduced for several reasons when compared to F2F course versions. For example, in asynchronous remote TBL courses, students report difficulty finding common times to complete team activities (Arcila Hernández et al., 2021; Palsole and Awalt, 2008). This could divide teams into smaller sub-teams or prevent some members from attending team meetings, both of which could negatively impact team cohesion and student learning (Goñi et al., 2020; Wildman et al., 2021). A second concern with remote collaborative learning is that instructors in asynchronous courses are not present during team activities and would not be able to facilitate discussions and provide guidance to teams during the learning activity. Students may also find it challenging to become familiar with the software and online tools used in remote collaboration (Arcila Hernández et al., 2021). Furthermore, in synchronous remote courses, instructors could experience difficulty monitoring web-based video conference breakout rooms and providing real-time feedback to teams. Finally, in both the synchronous and asynchronous formats, students could experience internet connectivity issues, which may further hinder online learning and collaboration with teammates (Anas et al., 2022; Jumat et al., 2020). Taken together, these online-specific learning barriers could limit students' ability to fully engage with their teammates, develop their collaborative skills, and ultimately deepen their learning to the same degree they would be able to for in-person course versions.

Despite the challenges associated with remote collaborative learning, the core elements of high structure active learning courses that promote learning (feedback, retrieval practice, and peer elaboration) (Dunlosky et al., 2013; Schmidt et al., 2019) would be equally present in both ERT and F2F course versions. Indeed, there is growing evidence that remote collaborative learning can be an effective delivery method to promote student learning (Anas et al., 2022; Blondeel et al., 2021; DeMasi et al., 2019; Divjak et al., 2022; dos Santos Belmonte et al., 2022; Franklin et al., 2016; Govindarajan and Rajaragupathy, 2022; Jumat et al., 2020; Sannathimmappa et al., 2022; Vannini et al., 2022). While these initial findings indicate that collaborative learning can be implemented successfully in a remote environment, much work remains to be done to better understand the impacts of ERT on student learning and course satisfaction in team-based undergraduate courses. In particular, it would be valuable to know whether remote teamwork negatively affects team dynamics and performance. To this end, we examined student performance on individual and team assessments in three different undergraduate neuroscience courses, taught using collaborative F2F or ERT by the same instructor. We also tracked measures of course and instructor satisfaction, as well as time spent per week on the course outside of class. Our findings demonstrate that, for the most part, the students in these ERT collaborative learning courses performed at levels comparable to a traditional classroom setting.

## MATERIALS AND METHODS

This study was approved by the Duke University Institutional Review Board. The data analyzed in this study were taken from 300- to 400-level undergraduate neuroscience courses and taught at a research university in the southeastern United States. The same instructor (TMN he/him) taught all course terms and had nine years of teaching experience at the university level prior to the start of the fall 2020 term.

Three different undergraduate neuroscience courses were analyzed in this study. The first was a 300-level methods course, which counts as an elective or laboratory requirement in the neuroscience major. The enrollment sizes over the three course terms were 57 (ERT, Spring 2021), 41 (F2F, Fall 2021 ), and 40 (F2F, Spring 2022) students. In Spring 2021 and Fall 2021, the majority of students were 3$^{rd}$ year and neuroscience majors. In Spring 2022, the students were a mix of neuroscience majors and undeclared. Most students were either 2$^{nd}$ or 3$^{rd}$ year. The

second course in the study was a 300-level seminar that counts as an elective toward the neuroscience major. Enrollment sizes were 17 (ERT, Spring 2021) and 18 (F2F, Spring 2022). The majority (> 70%) of students in Spring 2021 and Spring 2022 were 4th year and neuroscience majors. The third course in this study was a 400-level seminar, which counts as an elective for the neuroscience major. Enrollment sizes were 18 (ERT, Fall 2020) and 18 (F2F, Fall 2021), and the majority (> 75%) of students in each course term were 4th year and neuroscience majors.

The courses in this study were taught using a collaborative learning format based on team-based learning (TBL) (Michaelsen et al., 2004; Michaelsen and Sweet, 2008). Most of the major design elements of TBL were followed (preparatory phase, individual readiness assurance, and application activity), except that the team readiness assurance test (tRAT) was not used. The tRAT was removed to decrease the number of times that ERT students met outside of class time. In both ERT and F2F course versions, teams of six were assigned and students worked with the same teammates throughout the entire semester.

In the F2F course versions (Fall 2021 and Spring 2022), students first watched an introductory lecture, previously recorded and shared on YouTube© and were then provided assigned readings and slides. This preparatory phase was done outside of regular class time. Then, during the first class meeting of the module, students were given an opportunity to ask questions about the video lecture at the start of class. Next, students began the individual readiness assurance test (iRAT). The in-class iRAT was open book/resource and students had a time limit of 15-20 minutes. Students did not complete a tRAT. After the iRAT, students received immediate feedback and were given a mini-lecture to introduce the assigned journal article for the application activity. During the second-class meeting of the module, students completed an in-person application activity. The application activity typically involved answering questions related to a primary research article that had been assigned. Students were arranged into teams of six and all team members sat around tables facing each other. The instructor was present in the classroom during the application activity and routinely interacted with teams to answer student questions and guide discussions. Similar to standard TBL courses, students also completed peer evaluations of each other two times during the course term.

For the ERT course versions (Fall 2020 and Spring 2021), students had the opportunity to virtually attend the lecture live on Zoom© or to watch the recording on YouTube© outside of class time. The iRAT was also completed outside of class time with a time limit of 15-20 minutes. Similar to F2F terms, iRATs were open book/resource. Questions were randomly taken from a larger test bank and the order of answers was scrambled such that student quizzes were partly unique relative to each other. During the first virtual meeting of the ERT module, students met through Zoom© for feedback on iRAT answers, followed by a mini-lecture to introduce the new application activity. Next, students met with teammates virtually outside of class time to complete the application activity. Finally, in the second virtual meeting on Zoom©, students received feedback on the application activity and had an opportunity to report their answers.

Several different types of assessments were tracked in this study, including summative (final exam or midterm) and formative assessments (iRATs, application activities, and peer evaluations). For the 300-level methods course, a single cumulative final exam was given at the end of each course term. The final exam consisted of 50 multiple-choice questions, spread across Bloom's levels (Bloom, 1956) and covered all 10 learning modules. Identical or similar test questions were used between course terms. In the 300-level seminar course, we tracked student performance on the second midterm exam, which covered identical course material across each course term. The midterm consisted of 30 questions in the spring of 2021 and 32 questions in the spring of 2022. These multiple-choice test questions covered the range of Bloom's lower- and higher-order levels. Finally, for the 400-level seminar course, student performance on the first midterm exam was tracked. The exam included 30 questions in the fall of 2020 and 31 questions in the fall of 2021. Identical or similar multiple-choice test questions were compared between terms.

iRAT and application activity scores reported in this study represent the average class performance across individual assessments. iRATs consisted of 10 multiple-choice questions in each course, focusing on Bloom's levels of recall, understand, and to a lesser extent, apply. Application activity questions were either short answer, multiple choice, or required students to generate a diagram to summarize data. These activities addressed Bloom's higher-order levels of apply, analyze, synthesize, and evaluate. In the cases where course content or specific modules changed between years, those iRATs and application activities were excluded from the analysis. All iRATs and application activities were taken open book/resource.

Peer evaluation scores were calculated based on a survey that was released to the class (Michaelson et al., 2008). Students were asked to rate their teammates on a scale of 1 to 5 for each question and peer evaluation scores represent the summation of scores from the following questions:

1. My teammate comes to team meetings on time and stays engaged throughout the session.
2. My teammate asks useful questions and is focused on relevant class goals.
3. My teammate demonstrates a helpful balance of active listening and vocal participation.
4. My teammate is well-prepared for activities, and demonstrates expected depth of knowledge.
5. My teammate asks questions or explains concepts in a respectful way to everyone.

Survey questions measuring course quality, instructor quality, and hours per week outside of class were taken from end-of-semester course evaluations. The course evaluations were collected by the Office of Assessment and were available for review after student grades were posted. The evaluations were completed during class time, either in

person (F2F) or during a live Zoom© session (ERT). Twenty minutes of class time were given to complete the survey.

For Fall 2021 and Spring 2022, students provided answers to the following questions on a Likert scale (1 = poor, 2 = marginal, 3 = average, 4 = very good, and 5 = excellent): "Considering all components of the course (lectures, discussions, sections/labs, assessments, projects, course environment, etc.), overall the course was", and "Based on the effectiveness of instruction (clarity, expertise, enthusiasm, rigor, support, inspiration, etc.), overall the instructor was". In Fall 2020 and Spring 2021, students provided answers to the following questions on the above Likert scale: "Overall the course was", and "Overall the instructor was". Finally, across all semesters, students indicated the number of hours in a typical week they spent on this course (outside of class meetings), from 1 to 10 hours.

Statistical analysis was performed in IBM SPSS© and Stata©. Nonparametric, Mann U Whitney and Kruskal-Wallis H tests were performed to look for differences between groups.

## RESULTS

In the 300-level methods course, we were not able to detect significant differences across the three course terms (Spring 2021-ERT, Fall 2021-F2F, Spring 2022-F2F) for peer evaluation scores, iRATs, team application activities, instructor quality, course quality, or hours per week outside of class meetings (Table 1). Summative exam performance, however, was significantly different across course terms (Kruskal-Wallis test, $H = 14.820$, $p = 0.001$), with the students in ERT outperforming students in both F2F course versions (Table 1). Post hoc tests revealed differences for summative exam scores between ERT (Spring 2021) and F2F (Fall 2021) (Mann-Whitney U test, $U = 833$, $p = 0.020$), as well as between ERT (Spring 2021) and F2F (Spring 2022) (Mann-Whitney U test, $U = 614$, $p < 0.001$). The final exam in the Fall 2021-F2F course was taken remotely (non-proctored), while the final exam in the Spring 2022-F2F was completed in person (proctored). Importantly, we did not detect significant differences between Fall 2021-F2F and Spring 2022-F2F (Mann-Whitney U test, $U = 685.5$, $p = 0.202$), even though the final exams were offered in two different settings (remote vs in person).

Next, we tracked student performance and survey responses from the 300-level seminar course across two terms, Spring 2021 ERT and Spring 2022 F2F, as well as a 400-level seminar course across terms, Fall 2020 ERT and Fall 2021 F2F. No significant differences were observed for any of the assessment types or survey responses in these two different seminar courses (Tables 2 and 3).

## DISCUSSION

In this study, we addressed whether student and team performance differed between F2F and ERT versions of collaborative learning courses. Using three different undergraduate neuroscience classes, all taught by the same instructor, we tracked summative exam scores, individual quiz scores, team application activities, peer evaluations, student-perceived course and instructor quality, and self-reported hours devoted to the course outside of class time. Importantly, our findings reveal that none of the student content knowledge outcomes measured were negatively impacted in ERT (Tables 1-3). Rather, for one of the courses analyzed, we found that student performance in ERT was greater than F2F (Table 1). No other measures - individual quizzes, team activities, peer evaluation, course difficulty, instructor quality, and self-reported hours devoted to the course were significantly different between course versions.

**Table 1. 300-Level Methods Course**

| | Spring 2021 (ERT) | | | Fall 2021 (F2F) | | | Spring 2022 (F2F) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | Mean | SD | n | Mean | SD | n | Mean | SD | (H) | p-value |
| Peer Evaluation 1 | 57 | 98.93 | 2.57 | 41 | 99.37 | 1.22 | 40 | 98.35 | 3.75 | 2.176 | 0.337 |
| Peer Evaluation 2 | 56 | 99.77 | 0.66 | 41 | 99.2 | 2.24 | 40 | 98.92 | 2.81 | 3.754 | 0.153 |
| iRATs | 56 | 88.08 | 5.86 | 41 | 88.14 | 4.15 | 40 | 89.67 | 4.74 | 1.027 | 0.598 |
| Team Applications | 56 | 98.07 | 4.79 | 41 | 96.91 | 1.82 | 40 | 97.85 | 1.39 | 0.346 | 0.841 |
| **Summative Exam** | **56** | **91.75** | **6.66** | **41** | **87.07** | **9.95** | **40** | **85.10** | **10.55** | **14.820** | **0.001** |
| Instructor Quality | 37 | 4.865 | 0.41 | 38 | 4.711 | 0.61 | 32 | 4.781 | 0.49 | 1.571 | 0.456 |
| Course Quality | 37 | 4.541 | 0.60 | 38 | 4.316 | 0.74 | 32 | 4.375 | 0.79 | 1.781 | 0.410 |
| Hours / Week | 37 | 4.570 | 1.83 | 38 | 4.324 | 1.90 | 32 | 3.938 | 1.89 | 3.208 | 0.201 |

*Table 1.* Descriptive statistics for the Spring 2021, Fall 2021, and Spring 2022 course terms. At the start of each semester, Spring 2021 had 57 students enrolled, Fall 2021 had 41 students enrolled, and Spring 2022 had 40 students enrolled. ERT = emergency remote teaching. F2F = traditional face-to-face instruction. n = the total number of students completing survey questions or the total number students completing the assessment. SD = standard deviation. Mean = the average assessment or Likert score. iRATs = individual readiness assurance test. Kruskal-Wallis tests were used to compare responses or scores between the three groups. P values are shown for each category and bold text indicates statistically significant differences between groups.

**Table 2. 300-Level Seminar Course**

| | Spring 2021(ERT) | | | Spring 2022 (F2F) | | | | |
|---|---|---|---|---|---|---|---|---|
| | n | Mean | SD | n | Mean | SD | (U) | p-value |
| Peer Evaluation 1 | 17 | 99.12 | 1.76 | 18 | 99.73 | 0.48 | 139.0 | 0.562 |
| Peer Evaluation 2 | 17 | 99.30 | 1.99 | 18 | 99.60 | 0.69 | 133.5 | 0.356 |
| iRATs | 17 | 87.06 | 10.25 | 18 | 93.56 | 2.90 | 9.0 | 0.463 |
| Team Applications | 17 | 100.00 | 0.00 | 18. | 100.00 | 0.00 | 12.5 | 1.000 |
| Summative Exam | 17 | 87.45 | 10.31 | 18 | 90.45 | 6.73 | 120.5 | 0.281 |
| Instructor Quality | 12 | 5.00 | 0.00 | 11 | 4.91 | 0.30 | 60.0 | 0.296 |
| Course Quality | 12 | 4.83 | 0.39 | 11 | 4.81 | 0.60 | 62.0 | 0.674 |
| Hours / Week | 12 | 3.67 | 1.15 | 11 | 3.55 | 1.21 | 62.5 | 0.821 |

*Table 2.* Descriptive statistics for the Spring 2021 and Spring 2022 course terms. At the start of each semester, Spring 2021 had 17 students enrolled and spring 2022 had 18 students enrolled. ERT = emergency remote teaching. F2F = traditional face-to-face instruction. n = the total number of student responses completing a survey question or the total number students completing the assessment. SD = standard deviation. Mean = the average assessment or Likert score. iRATs = individual readiness assurance test. Mann-Whitney U tests were used to compare responses or scores between the two groups. P values are shown for each category and no significant differences were observed between groups.

**Table 3. 400-Level Seminar Course**

| | Fall 2020 (ERT) | | | Fall 2021 (F2F) | | | | |
|---|---|---|---|---|---|---|---|---|
| | n | Mean | SD | n | Mean | SD | (U) | p-value |
| Peer Evaluation 1 | 18 | 99.67 | 1.18 | 18 | 99.96 | 0.19 | 152.0 | 0.509 |
| Peer Evaluation 2 | 18 | 100.00 | 0.00 | 18 | 99.73 | 0.67 | 135.0 | 0.075 |
| iRAT | 18 | 91.66 | 4.04 | 18 | 91.48 | 6.78 | 16.50 | 0.806 |
| Application Activity | 18 | 99.36 | 1.43 | 18 | 100.00 | 0.00 | 10.00 | 0.317 |
| Summative Exam | 18 | 89.63 | 11.14 | 18 | 84.05 | 11.90 | 123.0 | 0.214 |
| Instructor Quality | 17 | 5.00 | 0.00 | 17 | 4.88 | 0.33 | 127.5 | 0.151 |
| Course Quality | 17 | 4.82 | 0.39 | 17 | 4.76 | 0.75 | 137.5 | 0.695 |
| Hours / Week | 17 | 4.76 | 1.92 | 18 | 4.89 | 1.45 | 139.0 | 0.637 |

*Table 3*. Descriptive statistics for the Fall 2020 and Fall 2021 course terms. At the start of each semester, Fall 2020 had 18 students enrolled, and Fall 2021 had 18 students enrolled. ERT = emergency remote teaching. F2F = traditional face-to-face instruction. n = the total number of student responses completing a survey question or the total number students completing the assessment. SD = standard deviation. Mean = the average assessment or Likert score. iRATs = individual readiness assurance test. Mann Whitney U tests were used to compare responses or scores between the two groups. P values are shown for each category and no significant differences were observed between groups.

*Individual Performance in Remote Collaborative Courses*

At first glance, the increased student performance in ERT or lack of a difference may seem surprising, especially given the challenges faced by students in remote courses during the pandemic (Brown, 2021; Hiler et al., 2021; Lee et al., 2021; Lemay et al., 2021) and the potential difficulties with online collaboration (Anas et al., 2022; Goñi et al., 2020; Jumat et al., 2020; Palsole and Awalt, 2008; Wildman et al., 2021). Our results, however, are consistent with several studies that have found either no difference in performance between students in ERT and F2F (AbdelSalam et al., 2021; Al-Zohbi et al., 2022; Blondeel et al., 2021; El Said, 2021; Engelhardt et al., 2021) or that ERT scores increased relative to pre-pandemic averages (Al-Zohbi et al., 2022; Elzainy et al., 2020; Iglesias-Pradas et al., 2021; McMurtrie, 2021). These findings also match up with pre-pandemic studies demonstrating no difference in student performance between online and F2F course versions (Bernard et al., 2004; Jahng et al., 2007; Means et al., 2013).

Possible explanations for the increased performance with ERT in higher education have been attributed to improved course design, better communication with students, increased support and flexibility, clearer expectations, increased time studying, and new digital tools and resources to support student learning (Abdullah et al., 2022; Fox et al., 2021; McMurtrie, 2021; Puang, 2021). Other factors that might improve student performance also include decreased course difficulty and increased academic dishonesty (Cavanaugh et al., 2022; McMurtrie, 2021). In our study, the textbooks, assigned readings, course topics and number of topics covered were similar between F2F and ERT course versions, and we saw no differences in self-reported hours per week outside of class time (Tables 1-3). Also, iRATs and exams were similar in content and length between course terms, and all assessments were open book. Therefore, students had similar resources available during testing, and we would argue against a decrease in difficulty with our ERT course. While we cannot exclude the possibility of unsanctioned collaboration on individual assessments in the ERT course terms, steps were taken to limit the possibility of sharing answers. This included the use of timed-assessments and unique assessments, randomly generated from a bank of test questions. In addition, we detected no difference in exam performance for the F2F course terms between in person (proctored) or remote final exam formats (non-proctored), suggesting that scores were not influenced by the presence of the instructor in the classroom.

The student performance data in our study are also consistent with recent literature from online and ERT TBL courses. When comparing online TBL to F2F TBL (pre-pandemic), no change in performance on individual assessments was observed between course versions (DeMasi et al., 2019; Franklin et al., 2016), though students did report a preference for F2F TBL compared to online TBL (DeMasi et al., 2019). In a second study, conducted at the start of the pandemic, student performance in ERT TBL did not differ from pre-pandemic F2F TBL (Blondeel et al., 2021). A possible explanation for this lack of difference could be that the core elements of TBL that promote learning (timely feedback, retrieval practice, and peer elaboration) are present in both ERT and F2F course versions (Dunlosky et al., 2013; Schmidt et al., 2019).

*Team Performance in Remote Collaborative Courses*

We also tracked team performance on application activities and measures of team dynamics by peer evaluation scores in the ERT and F2F course versions. The peer evaluations asked several questions about teammates, including arriving to meetings on time and staying engaged, demonstrating a balance of active listening and vocal participation, asking useful questions and focusing on relevant goals, being well prepared, and being respectful to everyone. While a few students in each ERT course expressed concerns about finding a convenient time to meet with teammates, the similar peer evaluation scores across ERT and F2F terms suggested that, for these collaborative courses, team dynamics did not significantly decline in the remote environment (Tables 1, 2, and 3). Furthermore, we see evidence that collaborative skills and team performance in ERT courses were similar to F2F, as scores on application activities were not significantly different between course versions (Tables 1-3). Importantly, studies on ERT TBL have found that students reported that the experience allowed them to build their collaborative skills, as well as motivating them to attend class sessions to support their teammates (dos Santos Belmonte et al., 2022; Govindarajan and Rajaragupathy, 2022).

*Instructor Support in Remote Environments*

Previous research on remote learning has suggested that in order for students to be successful, instructors must help cultivate a sense of community and work hard to establish a social presence with students (Collins et al., 2019; Dorneich et al., 2021; Jackson et al., 2020; Wong et al., 2020). A potential concern in asynchronous collaborative courses is reduced instructor access and presence, especially during team application activities. While students may be able to contact instructors through electronic mail and other online communication forms, the instructor cannot observe each group's verbal and non-verbal cues or provide assistance as quickly when teams require support (Wong et al., 2020). Unlike the F2F course versions in this study, the ERT terms did not have the benefit of real-time instructor feedback during asynchronous individual or team assessments. Surprisingly, measures of student-perceived course and instructor quality did not change with ERT, and all course quality ratings were in the range of 4.3-4.8 out of 5 (Tables 1-3). Similar to the F2F courses, the instructor in ERT did offer weekly office hours by Zoom© and was available by electronic mail for questions, usually with a response time of less than 24 hours. Therefore, the ERT course format still allowed for open lines of communication between the instructor and students, which may have contributed to the similar ratings for course and instructor quality.

*Limitations*

In our study, we have only examined student performance in three courses at a single university with small to medium enrollments. As such, additional studies will be needed to extend and generalize our findings. It would be useful to track student and team performance in courses from a variety of class sizes, disciplines, and universities. Indeed, student perception of TBL course quality can decrease in high-enrollment F2F courses (Ng and Newpher, 2021). Thus, further work should be done to address whether class size also impacts the student experience in remote collaborative courses. Furthermore, our study focused on second-, third-, and fourth-year students, but the data did not include first-year college students. Given the additional challenges faced by first-year students when adjusting to life on a new campus, the performance outcomes in ERT with this group should also be explored.

The collaborative courses in our study did not follow the complete TBL process and, for this reason, we did not classify them as TBL courses. Furthermore, the remote team activities in this study were completed outside of class time. It will be important in future studies to compare team performance between synchronous and asynchronous remote courses to address the importance of access to the instructor during team exercises. Also, our measures of team dynamics included peer evaluation scores, as well as team scores on application activities. We have not, however, observed student behaviors during team meetings, and the findings do not provide a complete picture of peer interactions during collaborative learning exercises. Furthermore, the scores on the team application activities and peer evaluations were in the range of 96-100%. These measures likely have a ceiling effect, which may have influenced our ability to detect differences between groups.

Finally, it is important to note that the instructor in this study had been using TBL for four years prior to the start of the fall 2020 semester. It is likely that the instructor's pre-pandemic experience with TBL helped ease the transition to remote collaborative learning and may have contributed to the student performance outcomes in this study. For new instructors or instructors with little experience implementing collaborative learning, great care should be taken to follow best practices for remote teamwork and to build an online classroom community (Clark et al., 2021; Li et al., 2021; Malik and Malik, 2022; Palsole and Awalt, 2008; Takizawa et al., 2021).

*Summary*

In conclusion, our findings suggest that for the ERT collaborative learning courses in this study, there were no negative impacts on student performance, individually or with teammates. This work supports the growing body of literature suggesting that student content knowledge outcomes can be maintained in remote collaborative learning environments.

## REFERENCES


AbdelSalam HM, Pilotti MAE, El-Moussa OJ (2021) Sustainable math education of female students during a pandemic: online versus face-to-face instruction. Sustainability 13:12248. doi: 10.3390/su132112248

Abdullah NA, Shamsi NA, Jenatabadi HS, Ng BK, Mentri KAC (2022) Factors affecting undergraduates' academic performance during COVID -19: fear, stress and teacher-parents' support. Sustainability 14:7694. doi: 10.3390/su14137694

Al-Zohbi G, Pilotti MAE, Abdelsalam H, Elmoussa O (2022) Learning physics online or face-to-face: A case study of STEM and non-STEM students. Frontiers in Psychology 13:1041187. doi: 10.3389/fpsyg.2022.1041187

Anas S, Kyrou I, Rand-Weaver M, Karteris E (2022) The effect of online and in-person team-based learning (TBL) on undergraduate endocrinology teaching during COVID-19 pandemic. BMC Med Educ 22:9. doi: 10.1186/s12909-022-03173-5

Arcila Hernández LM, Zamudio KR, Drake AG, Smith MK (2021) Implementing team-based learning in the life sciences: A case study in an online introductory level evolution and biodiversity course. Ecology and Evolution 11:3527-3536. doi: 10.1002/ece3.6863

Bernard RM, Abrami PC, Lou Y, Borokhovski E, Wade A, Wozney L, Wallet PA, Fiset M, Huang B (2004) How does distance education compare with classroom instruction? a meta-analysis of the empirical literature. Review of Educational Research 74:379-439. doi: 10.3102/00346543074003379

Blondeel E, Everaert P, Opdecam E (2021) And then there was COVID -19: do the benefits of cooperative learning disappear when switching to online education? Sustainability 13:18. doi: 10.3390/su132112168

Bloom B (1956) Taxonomy of educational objectives: The classification of educational goals. New York, Longmans, Green.

Bonwell C, Eison J (1991) Active learning: creating excitement in the classroom. In ASHE-ERIC Higher Education Reports, pp. 1-120. Education Rsources Information Center Document ED336049, Washington, DC: Institute of Education Sciences and U.S. Department of Education. Available at https://eric.ed.gov/?id=ED336049.

Brown S (2021) Did COVID break students' mental health? as the fall semester begins, students are stressed out and burned out. Chronicle of Higher Education, August 24, Available at https://www.chronicle.com/article/did-covid-break-students-mental-health

Carr S (2000) As distance education comes of age, the challenge is keeping the students. Chronicle of Higher Education, February 11. Available at https://www.chronicle.com/article/as-distance-education-comes-of-age-the-challenge-is-keeping-the-students/

Cavanaugh J, Jacquemin SJ, Junker CR (2022) variation in student perceptions of higher education course quality and difficulty as a result of widespread implementation of online education during the COVID-19 pandemic. Technology, Knowledge and Learning. doi: 10.1007/s10758-022-09596-9

Clark MC, Merrick LC, Styron JL, Dolowitz AR (2021) Orientation principles for online team-based learning courses. New Directions for Teaching and Learning 2021:11-23. doi: 10.1002/tl.20433

Collins K, Groff S, Mathena C, Kupczynskı L (2019) Asynchronous video and the development of instructor social presence and student engagement. Turkish Online Journal of Distance Education 20:53-70. doi: 10.17718/tojde.522378

DeMasi J, Harvan RA, Luca M (2019) Online and in-class team-based learning in undergraduate immunology: a comparative analysis. Medical Science Educator 29:1193-1199. doi: 10.1007/s40670-019-00814-1

Divjak B, Rienties B, Iniesto F, Vondra P, Žižak M (2022) Flipped classrooms in higher education during the COVID-19 pandemic: findings and future research recommendations. International

Journal of Educational Technology in Higher Education 19:9. doi: 10.1186/s41239-021-00316-4

Dorneich MC, O'Dwyer B, Dolowitz AR, Styron JL, Grogan J (2021) Application exercise design for team-based learning in online courses. New Directions for Teaching and Learning 2021:41-52. doi: 10.1002/tl.20435

dos Santos Belmonte I, Borges AV, Garcia ITS (2022) Adaptation of physical chemistry course in COVID-19 period: reflections on peer instruction and team-based learning. Journal of Chemical Education 99:2252-2258. doi: 10.1021/acs.jchemed.1c00529

Dunlosky J, Rawson KA, Marsh EJ, Nathan MJ, Willingham DT (2013) Improving students' learning with effective learning techniques: promising directions from cognitive and educational psychology. Psychol Sci Public Interest 14:4-58. doi: 10.1177/1529100612453266

El Said GR (2021) How Did the COVID-19 pandemic affect higher education learning experience? an empirical investigation of learners' academic performance at a university in a developing country. Advances in Human-Computer Interaction 2021:6649524. doi: 10.1155/2021/6649524

Elzainy A, El Sadik A, Al Abdulmonem W (2020) Experience of e-learning and online assessment during the COVID-19 pandemic at the College of Medicine, Qassim University. Journal of Taibah University Medical Sciences 15:456-462. doi: 10.1016/j.jtumed.2020.09.005

Engelhardt B, Johnson M, Meder ME (2021) Learning in the time of Covid-19: Some preliminary findings. International Review of Economics Education 37:100215. doi: 10.1016/j.iree.2021.100215

Fox K, Bryant G, Lin N, Khedkar N, Nguyen A (2021) Time for class – COVID -19 edition part 3: The impact of 2020 on introductory faculty and their students. New York, NY: Tyton Partners. Available at https://everylearnereverywhere.org/wp-content/uploads/Time-for-Class-Covid-Part-3-V2.pdf.

Franklin AS, Markowsky S, De Leo J, Normann S, Black E (2016) Using team-based learning to teach a hybrid pharmacokinetics course online and in class. Am J Pharm Educ 80:171. doi: 10.5688/ajpe8010171

Fuchs K (2022) The difference between emergency remote teaching and e-learning. Front Educ 7:921332. doi: 10.3389/feduc.2022.921332

Goldhaber D, Kane T, McEachin AEM, Patterson T, Staiger D (2022) Research report: the consequences of remote and hybrid instruction during the pandemic. Cambridge, MA: Center for Education Policy Research, Harvard University.

Goñi J, Cortázar C, Alvares D, Donoso U, Miranda C (2020) Is teamwork different online versus face-to-face? a case in engineering education. Sustainability 12:10444. doi: 10.3390/su122410444

Govindarajan S, Rajaragupathy S (2022) Online team based learning in teaching Biochemistry for first year MBBS students during COVID-19 pandemic. Biochemistry and Molecular Biology Education 50:124-129. doi: 10.1002/bmb.21598

Hiler T, Nguyen S, Fishman, R (2021) One semester later: how prospective and current college students' perspectives of higher ed have changed between August and December 2020 Third Way, January 21. Available at https://www.thirdway.org/memo/one-semester-later-how-prospective-and-current-college-students-perspectives-of-higher-ed-have-changed-between-august-and-december-2020

Hodges C, Moore S, Lockee B, Trust T, Bond A (2020) The difference between emergency remote teaching and online learning. Educause Review, March 27. Available at https://er.educause.edu/articles/2020/3/the-difference-between-emergency-remote-teaching-and-online-learning

Iglesias-Pradas S, Hernández-García Á, Chaparro-Peláez J, Prieto JL (2021) Emergency remote teaching and students' academic performance in higher education during the COVID-19 pandemic: A case study. Computers in Human Behavior 119:106713. doi: 10.1016/j.chb.2021.106713

Jackson L, Otaki F, Powell L, Ghiglione E, Zary N (2020) Study of a COVID-19 induced transition from Face-to-Face to Online Team-Based Learning in Undergraduate Family Medicine [version 1]. MedEdPublish 9. doi: 10.15694/mep.2020.000232.1

Jahng N, Krug DH, Zhang Z (2007) Student Achievement in Online Distance Education Compared to Face-to-Face Education. The European Journal of Open, Distance and E-Learning 10.

Johnson D, Johnson R (1999) Learning together and alone: cooperative, competitive, and individualistic learning. 1st edition. Boston, MA: Allyn and Bacon.

Jumat MR, Wong P, Foo KX, Lee ICJ, Goh SPL, Ganapathy S, Tan TY, Loh AHL, Yeo YC, Chao Y, Cheng LTE, Lai SH, Goh SH, Compton S, Hwang NC (2020) From Trial to Implementation, Bringing Team-Based Learning Online-Duke-NUS Medical School's Response to the COVID-19 pandemic. Med Sci Educ 30(4):1649-1654. doi: 10.1007/s40670-020-01039-3

Lee J, Solomon M, Stead T, Kwon B, Ganti L (2021) Impact of COVID-19 on the mental health of US college students. BMC Psychology 9:95. doi: 10.1186/s40359-021-00598-3

Lemay DJ, Bazelais P, Doleck T (2021) Transition to online learning during the COVID-19 pandemic. Computers in Human Behavior Reports 4:100130. doi: 10.1016/j.chbr.2021.100130

Leonhardt D (2022) Not Good for Learning. In New York Times, May 5, Available at https://www.nytimes.com/2022/05/05/briefing/school-closures-covid-learning-loss.html.

Li Y, Sears NA, Murray Ian VJ, Yadav KK (2021) Rethinking Teaching Team-Based Learning: The Challenges and Strategies for Medical Education in a Pandemic. AERA Open 7. doi: 10.1177/23328584211067207

Maimaiti G, Jia C, Hew KF (2021) Student disengagement in web-based videoconferencing supported online learning: an activity theory perspective. Interactive Learning Environments 1-20. doi: 10.1080/10494820.2021.1984949

Malik AS, Malik RH (2022) Twelve tips for conducting team-based learning session online in synchronous setting. Medical Teacher 44:486-493. doi: 10.1080/0142159X.2021.1910642

McMurtrie B (2021) Good Grades, Stressed Students. Chronicle of Higher Education, March 17. Available at https://www.chronicle.com/article/good-grades-stressed-students.

Means B, Toyama Y, Murphy R, Baki M (2013) The Effectiveness of Online and Blended Learning: A Meta-Analysis of the Empirical Literature. Teachers College Record 115:1-47. doi: 10.1177/016146811311500307

Michaelsen L, Knight A, Fink L (2004) Team-based learning: A transformative use of small groups in college teaching. Sterling, VA: Stylis Publishing.

Michaelsen L, Par-malee D, McMahon K, Levine R (2008) Team-Based Learning for Health Professions Education. Sterling, Va.: Stylus.

Michaelsen L, Sweet M (2008) The essential elements of team-based learning. New Dir Teach Learn 116:7-27. doi: 10.1002/tl.330

Mitchell C, Cours Anderson K, Laverie D, Hass A (2021) Distance be damned: The importance of social presence in a pandemic constrained environment. Marketing Education Review 31:294-310. doi: 10.1080/10528008.2021.1936561

Nazempour R, Darabi H, Nelson PC (2022) Impacts on Students’ Academic Performance Due to Emergency Transition to Remote Teaching during the COVID-19 pandemic: a financial engineering course case study. Education Sciences

12:202. doi: 10.3390/educsci12030202
Ng M, Newpher T (2021) Class Size and Student Performance in a Team-Based Learning Course. J Undergrad Neurosci Educ 20:A49-A57.
Palsole S, Awalt C (2008) Team-Based Learning in Asynchronous Online Settings. New Directions for Teaching and Learning 2008(116):87-95.
Peacock S, Cowan J, Irvine L, Williams J (2020) An Exploration Into the Importance of a Sense of Belonging for Online Learners. The International Review of Research in Open and Distributed Learning 21:18-35. doi: 10.19173/irrodl.v20i5.4539
Puang S (2021) As Colleges Strive for a Return to Normal, Students with Disabilities Say, 'No Thanks'. Chronicle of Higher Education, May 11. Available at https://www.chronicle.com/article/as-colleges-strive-for-a-return-to-normal-students-with-disabilities-say-no-thanks.
Sannathimmappa MB, Nambiar V, Aravinkakshan R, Kumar A (2022) Are Online Synchronous Team-Based-Learning (TBL) pedagogy effective?: Perspectives from a study on medical students in Oman. Journal of Advances in Medical Education & Professionalism 10:12-21. doi: 10.30476/jamp.2021.92361.1481
Schmidt HG, Rotgans JI, Rajalingam P, Low-Beer N (2019) A Psychological Foundation for Team-Based Learning: Knowledge Reconsolidation. Acad Med 94:1878-1883.doi: 10.1097/ACM.0000000000002810
Springer L, Stanne M, Donovan S (1999) Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: a meta-analysis. Review of Educational Research 69:21-51. doi: 10.3102/00346543069001
Swanson E, McCulley L, Osman D, Lewis N, Solis M (2019) The effect of team-based learning on content knowledge: A meta-analysis. Active Learning in Higher Education 20(1):39-50. doi: 10.1177/1469787417731201
Takizawa PA, Honan L, Brissette D, Wu BJ, Wilkins KM (2021) Teamwork in the time of COVID-19. FASEB BioAdvances 3:175-181. doi: 10.1096/fba.2020-00093
Tanner KD (2013) Structure matters: twenty-one teaching strategies to promote student engagement and cultivate classroom equity. CBE Life Sci Educ 12:322-331. doi: 10.1187/cbe.13-06-0115
UNESCO (2021) One year into COVID-19 education disruption: where do we stand? UNCESCO Newsroom, March 19. Available at https://en.unesco.org/news/one-year-covid-19-education-disruption-where-do-we-stand.
Vannini V, Alberti S, Epifani C, Valentini O, Ferri P (2022) The effects of online Team-Based Learning on undergraduate nursing students' performance, attitudes and accountability during COVID-19 pandemic. Acta Biomedica Atenei Parmensis 93:e2022346. doi: 10.23750/abm.v93i6.13769
Wildman JL, Nguyen DM, Duong NS, Warren C (2021) Student teamwork during covid-19: challenges, changes, and consequences. Small Group Research 52:119-134. doi: 10.1177/1046496420985185
Wong P, Jumat M, Lee I, Foo K, Goh S, Ganapathy S, Lai S, Hwang N (2020) Redesigning team-based learning facilitation for an online platform to deliver preclinical curriculum: A response to the COVID-19 pandemic [version 1]. MedEdPublish 9:135. doi: 10.15694/mep.2020.000135.1

Received February 13, 2023; revised March 15, 2023; accepted March 15, 2023.

**Acknowledgements and Funding**
We thank Shelley Newpher, Minna Ng, and Ben Thier for helpful comments on this manuscript, and Grey Reavis for preparing the IRB and performing statistical tests. This work was funded by Duke University and the Charles Lafitte Foundation Program in Psychological and Neuroscience Research at Duke University, as well as the Duke Learning Innovation, Carry the Innovation Forward program.

**Conflict of Interest**
The Author(s) declare(s) that there is no conflict of interest.

Address correspondence to: Dr. Thomas Newpher, Department of Psychology and Neuroscience, 308 Research Drive, Duke University, Durham, NC 27708. Email: thomas.newpher@duke.edu