Student perceptions of weekly synchronous team quizzes in an online statistics course

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In a fully online college introductory statistics class, we incorporated a flexible synchronous course component to provide instructor immediacy and support students who are lacking sufficient prior knowledge when a new topic is introduced. We describe a learning cycle with weekly team quizzes inspired by the readiness assurance process of team-based learning; we interviewed eight students for their perceptions of the course structure. Team quizzes are designed to provide regular formative assessment and feedback in real-time with the goal of improving student satisfaction and success in the course. Overall, students reported that the weekly synchronous sessions contributed to a strong sense of belonging to peers and the instructor, were helpful for their learning and helped them successfully complete the course.

Implications for practice or policy:

- Instructors can use regular synchronous team quizzes in a fully online course to improve student engagement, connectedness, persistence and learning.
- Instructors can use team quizzes for regular formative assessment and feedback and to facilitate just-in-time intervention.

Keywords: synchronous, online education, statistics education, mathematics education, team-based learning (TBL), belonging, case study

Introduction

Institutions of higher education are expanding their online course offerings in mathematics and science to give distance learning students increased educational access and choice (Trenholm & Peshke, 2020). Although many studies suggest that online and in-person education have equivalent student achievement outcomes in many subjects (e.g., Müller & Mildenberger, 2021; Nguyen, 2015), some research does not (Tanyel & Griffin, 2014).

In particular, students in online mathematics and statistics courses often have lower grades and higher attrition rates than students in corresponding face-to-face courses (Smith & Ferguson, 2005; Trenholm & Peshke, 2020; Vilardi & Rice, 2014; Xu & Jaggers, 2011). Such findings are especially concerning since failure to complete introductory mathematics courses can be a barrier to persistence in majors in science, technology, engineering and mathematics and, ultimately, impact the ability of students to graduate (Daker et al., 2021; Parker, 2005). This problem is of particular importance due to possible pandemic-related educational deficiencies.

Most college-level mathematics and statistics courses are highly ordered and sequential (Guskey & Gates, 1986), which requires students to reach some level of mastery of early concepts before proceeding to later topics. In face-to-face classes, knowledge gaps can be identified and resolved immediately, but fully

online courses usually have little real-time interaction between students and their peers or the instructor, which is a possible barrier to success (Lin et al., 2017). In particular, group work that provides immediate feedback, encourages peer explanations and helps students develop a shared understanding of their struggles with mathematical problem-solving may be effective for learning mathematics (Webb, 1991). Widespread access to video conferencing (like Zoom) makes this type of online real-time interaction easier for students (Berges et al., 2021).

One way to create the opportunity for such group work to regularly assess student learning and increase both student-to-student and student-to-instructor interaction is with regular synchronous virtual meetings modelled on the team-based learning (TBL) readiness assurance process (RAP) (Michaelsen et al., 2004). Our team quiz sessions were designed to encourage peer discussion and allow the instructor to provide meaningful and timely feedback and intervention.

Literature review

Sense of belonging, collaborative learning and formative assessment

Student sense of belonging, as defined by Goodenow (1993, p. 25), is the student feeling "accepted, valued, included, and encouraged by others (teachers and peers) in the academic classroom". Sense of belonging is widely accepted as being important for student motivation and persistence (both course and degree completion), particularly in mathematics and in online courses (Hart, 2012; Lewis et al., 2017; Peacock et al., 2020; Pedler et al., 2022). In contrast, feelings of disconnectedness from teachers and peers and delayed communication contribute to attrition in online courses (Willging & Johnson, 2009). Liu et al. (2009) reported that social presence or the degree of person-to-person awareness in the online environment, as defined by Tu (2002), significantly predicts course retention and final grade in the community college online environment. Similarly, Muilenburg and Berge (2005) concluded that the primary barrier to student learning online is a lack of social interaction.

Collaborative learning increases contact and communication between students and has been found to be effective for student learning both generally (Laal & Ghodsi, 2012) and in mathematics specifically (Klang et al., 2021). However, student performance and attitudes depend on the type of collaboration (Capar & Tarim, 2015; Kyndt et al., 2013). Problems presented for students to work on should be challenging but doable with support. In addition, groups must be compelled to work together to achieve their goals rather than engaging in "divide and conquer" approaches. Finally, individuals must be held accountable for their contributions. (D'Mello & Graesser, 2012; Gillies, 2014; Mullins et al., 2011).

Collaborative learning can provide formative assessment if collaborations stimulate effective peer discussions and instruction and provide feedback that advances student learning (Wiliam & Thompson, 2008). Formative assessment can improve student achievement in mathematics, particularly through the use of brief regular testing (Boström & Palm, 2023).

Adapting TBL to undergraduate online mathematics and statistics

TBL was developed by Michaelsen et al. (2004) to encourage successful collaborative learning by following four principles: strategically diverse permanent teams, RAPs, team application activities during class time and peer reviews. TBL has been found to improve student learning outcomes in a variety of subjects (Haidet et al., 2014: Michaelsen et al., 2004) and in science, technology, engineering and mathematics in particular (Metoyer et al., 2014).

Paterson and Sneddon (2011, p. 879) concluded that TBL encourages mathematical thinking and that "this approach warrants more attention from the mathematics teaching community". Both students and instructors have revealed high levels of satisfaction using TBL for statistical literacy (St. Clair & Chihara, 2012). In addition, students have experienced improved performance and reported that TBL had a positive impact on their learning of statistics (Campbell & Taylor, 2020).

We focus on the RAP, which was designed to ensure that students are ready for authentic and challenging applications. The RAP has five parts: (a) independent content acquisition, (b) an individual multiple-choice test, (c) a team multiple-choice test over the same content with immediate feedback, (d) an appeals opportunity for students to demonstrate correct reasoning on questions marked incorrect on the team assessment and (e) a short clarifying lecture to correct misconceptions that were exposed during the assessments (Michaelsen & Sweet, 2008).

The structure of the RAP gives both students and the instructor formative feedback, so that the instructor can intervene and assist at the same time that the students become aware of their knowledge gaps. The individual test holds students accountable for their own knowledge, whereas the team test provides a common goal for collaborative learning as well as a venue for connecting with peers.

A body of literature from the Team-Based Learning Collaborative, a non-profit, volunteer-supported organisation, guides practitioners adapting traditional TBL to an online environment. Clark et al. (2018, p. 4) cautioned that "in the transition from a face-to-face TBL course, maintaining the integrity of the readiness assurance process is not necessarily straightforward". Although Clark et al. recommended using discussion boards for collaboration for the team test (denoted tRAT), online math students' discussion participation has been found to be about half that of students in English, communication or social science courses (Finnegan et al., 2009). In addition, online instructors in mathematics have found discussion forums to be problematic and do not believe that asynchronous discussion can effectively replace the just-in-time back-and-forth interaction necessary to guide students (Kemp & Grieve, 2014; Trenholm et al., 2016).

Synchronous sessions in fully online courses

Farrell and Brunton (2020) reported that informal interaction with peers either face-to-face or online engendered feelings of belonging and support, whereas discussion forums did not meet the support needs of some students. Robertson (2020) found that isolation and lack of interaction with peers was a main reason for student attrition, and that text-based discussion boards did little to prevent or mitigate the problem. Xu and Jaggars (2013) found that increased interaction between instructor and students in online courses predicted better student grades, and that doing this face-to-face (as through synchronous Zoom sessions) increased attendance and success as well. Hlapanis et al. (2006) found that synchronous discussions early in the course primarily established social bonds and trust between participants, whereas synchronous discussions later in the course concerned student learning and reflection. They also found that the most successful lessons had a higher degree of synchronous communication.

Although the Team-Based Learning Collaborative has suggested options to compensate for the lack of immediate feedback during the RAP when conducted asynchronously (Clark et al., 2018), we focus on how to use synchronous sessions to implement the tRAT to maintain the benefits of immediate feedback and team community building (Michaelsen & Sweet, 2008).

Methods

We used an exploratory and qualitative case study approach (Creswell, 1998) to capture and describe learners' experiences in this study. Yin (1989) stated that findings from a qualitative study may not be generalisable; however, this approach enables researchers to explore and theorise patterns and relationships that may otherwise remain undiscovered.

We implemented a modified TBL approach in a fully online introductory statistics course. We designed this single case study post-facto and guided participants to remember and describe the case during the semi-structured interviews (Reigeluth & Frick, 1999). Our guiding research questions (RQs, noted below in italics) and specific interview questions (posed to students) were:

- *RQ1. How do students perceive synchronous team sessions for their learning? What did you think about meeting synchronously for team quizzes?*
    - Was this type of session different from other courses?
    - What were your perceptions of interactions with other students?
- *RQ2. How do students perceive the optional workbook (help) sessions?*
    - How helpful were these sessions for your learning of course content?
    - How do these sessions compare to video instruction in other classes?
- *RQ3. What parts of the TBL learning sequence were perceived as most and least helpful?*
    - Which learning activities were the most and least helpful?
    - What suggestions do you have for changes?
    - How would you describe your overall class experience?

Context and setting

This investigation was conducted at a mid-sized public university in the inland north-west region of the United States of America which offers an undergraduate course in statistics in both face-to-face and fully online modes. Enrollment is approximately 800 students per year, with 130 in fully online sections. The course is required for biology and health sciences majors and is an option for other majors to prepare students for more advanced courses in research methods in their discipline.

Description of the instructors and course content

All students who were interviewed took the course from one of two faculty members: Faculty 1 (a clinical associate professor of mathematics with a PhD in applied probability) and Faculty 2 (a lecturer with a Master of Science in mathematics). After experiencing a particularly poor course pass rate in 2011, Faculty 1 adapted the TBL learning cycle to the face-to-face introductory statistics course to reduce student attrition and improve student learning. After teaching face-to-face using Faculty 1's adapted TBL learning cycle, Faculty 2 added synchronous sessions for the tRAT in the online modality. Both faculty members had these synchronous sessions in their fully online courses during Spring and Summer 2020.

The course covers basic descriptive statistics, study design and statistical inference with the t, F and chi-square distributions, including simple linear regression. Probability is covered within the context of hypothesis testing and interval estimation. Emphasis is placed on choosing and executing an appropriate procedure and on the interpretation of results using both correct statistical terminology and non-technical common language.

Description of the course pedagogy

Although the tRAT primarily involves learner-learner interactions, the modified TBL approach described in this paper scaffolds activities leveraging the interdependency of all three types of interactions (i.e., learner-learner, learner-instructor and learner-content) as identified by Moore (1989).

We organised the course to have a TBL learning cycle weekly, so that the amount of content covered by each RAP is manageable by lower-division students and the tRAT is easily completed during a short synchronous session. The individual multiple-choice tests (designated "pre-activities") are completed asynchronously prior to the tRATs (designated "team quizzes"), which are conducted synchronously over Zoom in breakout rooms. Our pre-activities give immediate feedback and multiple attempts; in effect, although the individual pre-activity and the team quiz cover the same content, specific questions differ. Pre-activities emphasise basic concepts and skills, while team quizzes have nuanced questions that students often miss on their own. Since some level of mastery is essential for progression to the application activities, team quizzes provide feedback to both the instructor and the student about what students have not yet mastered, and the synchronous session provides the opportunity for the instructor to give just-in-time correction. Both pre-activities and team quizzes are graded with low stakes towards their course grade. For team quizzes, student teams must discuss and agree on an answer choice for each

question, and if their choice is incorrect, they must rediscuss and choose again. Teams continue until correct answers are found, and penalties for each incorrect selection encourage discussion before choosing an answer.

Our modified TBL approach omits the TBL appeals process. Instead, we give time for student questions in the main Zoom room after students return from team quiz breakout rooms and may give a short clarifying lecture based on student difficulties that were exposed during the quizzes. The lecture is recorded and posted for students who are unable to stay after completing the quiz or who would like to rewatch later.

In classic TBL, after the RAP, students meet in their predetermined and permanent teams to collaboratively work on application problems. However, in our modified version, teams are formed ad hoc during each synchronous quiz session because this allows students more scheduling flexibility – key for many online students. Application exercises are contained in a workbook and completed by students individually and asynchronously, although optional synchronous sessions are offered each week for students to collaborate and ask the instructor questions. These are recorded and posted for all students to view. The cycle of learning activities is summarised in Figure 1 with elaboration in Table 1.

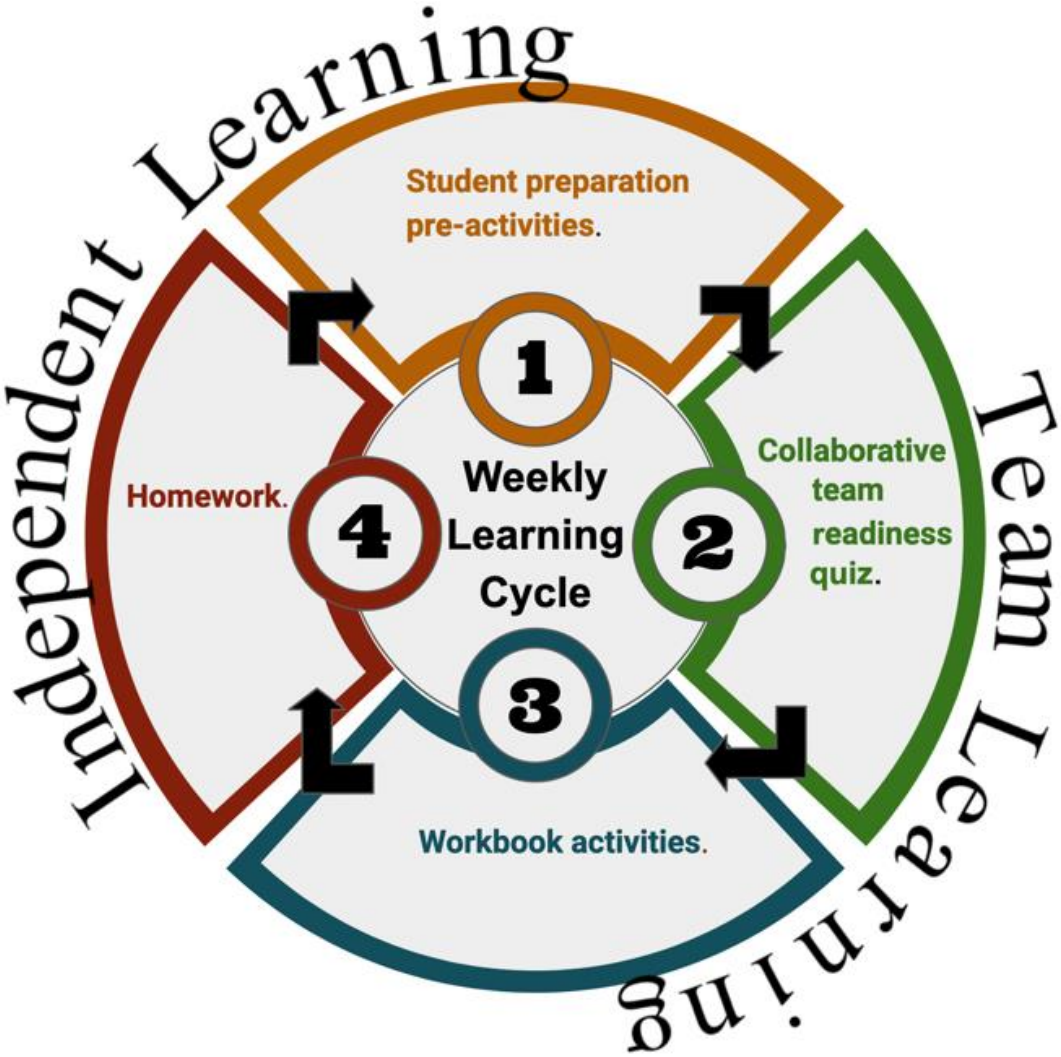

Figure 1. The weekly learning cycle in the Introduction to Statistics course

Table 1
The weekly learning cycle in the Introduction to Statistics course

	What students do	Purpose
Pre-activities	• Read text or watch video content introduction. • Take a short multiple-choice quiz online with immediate feedback, multiple tries and small error penalties.	• Introduction to content and review of prerequisite knowledge to ensure readiness for applications. • Students get early concept comprehension feedback.
	Team quiz logistics	**Purpose**
Collaborative team readiness quiz	• Zoom meeting times are determined by survey; 3 or 4 weekly times are chosen. • Students can join any of the available times each week without notifying the instructor in advance. • Instructor assigns 3–5 students per breakout room. • Questions are multiple choice with well-chosen distractors. • Consensus is required: One student answers, and the grade applies to all students on the team. • Students receive immediate feedback, multiple attempts, small error penalties and can continue until their answers are correct. • Instructor gives just-in-time assistance in breakout rooms.	• Formative assessment exposes and eliminates knowledge gaps. • Questions challenge students and reveal common misconceptions. • Students focus on a common goal and build a sense of belonging to the course. • Students share ideas and solutions. • Students have small early successes and gain confidence. • Students are able to quickly overcome obstacles and make progress. • Sessions provide instructor immediacy in order to reduce student anxiety and build problem-solving persistence.
	What students do	**Purpose**
Workbook activities	• Complete application problems. • Attend optional synchronous workbook sessions or watch video recordings.	• Give students space to articulate thoughts, explain concepts, practice, err and correct their work.
Homework	• Answer questions with immediate feedback and multiple penalty-free attempts.	• Facilitate skills practice and develop conceptual understanding of processes.

Additional pedagogical details

To reduce student anxiety and allow more discussion, team quizzes usually take 30–40 minutes but have a generous time limit of 1 hour. Students receive short verbal instructions and reminders about kind and professional team interaction, and the instructor actively solicits student buy-in to mitigate resistance. Students are told that mistakes are expected, have minimal grade impact and that questions are designed to require discussion, dispel misconceptions and contribute to successful course completion.

After some time, the instructor enters each Zoom breakout room, sometimes with the camera and microphone off in order to hear in-progress student discussion. The instructor can then make themselves visible and offer assistance (i.e., high social presence and high immediacy). The instructor communicates approachability and a willingness to help, giving praise for hard work even (especially) if initial answers are incorrect in order to encourage student persistence.

After completing the quiz, students return to the main Zoom room for instructor feedback and to ask questions. This approach helps students synthesise the knowledge that they co-constructed in the breakout room and, in effect, reinforces their learning.

Course technology

Course structure and some instructional materials are provided in a learning management system. Readings and application activities are in a workbook written for this course and pedagogy. Individual and team quizzes and homework are in WebAssign. Statistical computations are usually performed using R on Posit.cloud, although students are free to use any statistical software that they prefer.

Data collection

In this study, we employed convenience sampling (Yin, 1989) after obtaining approval from the university's institutional research board. Over 90 students in two online sections of introductory statistics taught during Spring and Summer 2020 were emailed a short study description and informed consent information. Nine students agreed to schedule an interview, but due to technical difficulties, transcripts from only eight students were obtained for study. The interview participants were six women and two men; the following table provides characteristics by participant.

Table 2
Participants

Student	Age range	Major	Online course experience
1	18–24	Health studies	Some
2	18–24	Radiologic science	Some
3	25–35	Kinesiology	None
4	36+	Psychological science	Some
5	18–24	Nursing	Some
6	18–24	Psychological science	High
7	18–24	Health science	Some
8	25–35	Psychological science	Some

Interview protocol

We conducted all but one interview in teams of two: one course instructor and one online instructional design professional. Informed consent was obtained prior to the interview process. To enhance objectivity in this study, the instructors did not interview students from their own classes. Each interview lasted approximately 1 hour. Students sometimes offered answers that led the interviewers in different directions than specified in the protocol. At such times, somewhat different questions were asked to clarify some of the student responses. All interviews were conducted via Zoom and then transcribed.

Data analysis

Four of us collaborated (Braun & Clarke, 2006) to analyse interview transcripts thematically. According to Wolcott (1994), thematic analysis allows researchers to define, reduce and create the illusion of coherence from large amounts of textual, partial, and often contradictory data. Notably, the analysis process began during the initial data interviews and continued after data collection (Davies, 1999). We

followed Taylor and Bogdan's (1984) systematic analysis approach, which involved regular and reflective review of the interview transcripts to produce and refine emerging themes. In effect, using interview transcripts, we (a) reviewed the findings, (b) generated initial codes, (c) searched for emerging patterns and themes, (d) reviewed the themes, (e) defined the themes and (f) generated the report. Codes were used to categorise answers to the specific interview questions listed above; if a student had a novel response, then a new code was generated. When we compared codes, we identified themes by frequency among students, overlapping ideas and by the students' emphasis (strong vs. weak response).

Credibility of the data is essential in qualitative research (Guba & Lincoln, 1981). For credibility and validity of results, we transcribed all interviews and developed a summary of key findings for participant review and member-checking. We sent all participants summaries for confirmation or clarification. If misunderstandings occurred, we revisited the findings to address the conflicting opinions and re-confirmed the information with the participants.

Results

RQ1. How do students perceive synchronous team sessions for their learning?

Students answered the first sub-question "What did you think about meeting synchronously for team quizzes?" by saying they appreciated being able to identify their knowledge or skill gap(s) and receive feedback and assistance in real time:

> I liked it because if I didn't completely know something … someone else in the group … could explain it to me … you got the information in different ways versus just one instructor. (Student 1)

> There were concepts that I didn't fully understand. And it allowed me to bounce my ideas or had someone else explain it to me from a different perspective. (Student 6)

> There's a big difference between, yeah, I conceptually understand it, and I can actually do it. I think there is some benefit to being in a group because I think then you can identify times or steps that you're like, "I don't quite know how I get from that step to that step," and somebody else in the group might be like, "Oh, that's the part I really understand". (Student 3)

Students reported that the team quizzes advanced their learning through discussions of their work with each other:

> I think [it] just helped me learn, I mean, when you teach it just solidifies that subject matter even further. So I think I learned more by helping. (Student 8)

> I think being able to combine your knowledge and the other students' knowledge together … I felt it helped to grow my knowledge in statistics (Student 5)

Students also recognised the value of instructor availability when meeting synchronously rather than relying on asynchronous communication, both for their ability to learn and for their sense of comfort:

> If I'm watching a prerecorded lecture or a video, I have to make a note and say, "Oh, I didn't quite understand that. Now I got to find a time to follow up". By the time I asked the question, I'm not in that mindset. (Student 3)

> She would pop in and out of the different rooms. We were able to call her in ... and she would jump over and help us out. She was very, very available in that. ... it was very helpful. (Student 4)

> I did feel surprisingly more connected to the instructor being able to talk virtually with her than when you're in a lecture hall and there's 200, 300 kids. (Student 5)

Finally, some students suggested that peer assistance during synchronous sessions contributed to their success in completing the course:

> One of the people in my group, they saw me on the video chat writing the whole thing out. Because we were trying to take turns to answer each question. And he's like, "Why are you doing it that way? Let me just ...". And he showed me how to do it on my calculator. And that was such a game changer for the rest of the semester. (Student 6)

> They taught me a lot. I was a bad student. I … did not know what I was doing halfway through. And if I ever got it wrong, they told me. (Student 3)

The second sub-question was "Was this type of session different from other courses?" One theme that emerged is that students perceived these team sessions as a replacement of traditional group projects and different from those because they shifted the organisational burden from students to the instructor:

> I liked the team quizzes [even though] I hate group work. The [other] classes, we're doing more just projects with set people ... we have to organise ourselves, record them ourselves ... So, it's hard ... With [statistics], it was nice because she just already had it all set up, and it was really easy to just go in, go in a group, and get everything done. It was just laid out for you really well. (Student 1)

> I've done quite a few online classes. I've had other online classes where there was group work. And that went very poorly … And most people take online classes to be flexible with their time, in kind of a get in, get out situation. With these team quizzes I think it provided that short time frame where we were all sitting down, committed to working on this quiz. (Student 6)

It was interesting to note that none of the interviewed students were surprised to have a weekly synchronous meeting as part of the course even though the course was fully online. However, there was initial apprehension from not knowing how the team quizzes worked:

> I was a little nervous just because stats is a lot different from other math classes I feel like. So being able to jump on to that synchronous meeting and be with everybody, it clarified how the course was going to work and how the content was for the class. (Student 5)

The third sub-question was, "What were your perceptions of interactions with other students?". The primary theme that emerged in response was that the synchronous quiz sessions enhanced students' sense of comfort, sense of belonging in the course and connectedness with their peers:

> It was a lot more connected even though it was online … being able to talk and ask questions. (Student 5)

> You build a rapport with your other students that allows that comfort to bounce ideas off of later in the semester. (Student 6)

> We struggled through them [the team quizzes] together. (Student 3)

In fact, students appreciated the regular social interaction under pandemic conditions. They often remained in breakout rooms after completing their quizzes, and some exchanged contact information to obtain help when stuck on problems:

> It was fun ...We would take our group quizzes and then we'd still be talking about our little weird COVID realities and then the professor would pop in and say, "Hi guys, you doing okay?". And we're like, "Yep, we've been done with the quiz for 20 minutes, we're just talking". It did provide an emotional connection that, at the time, was really necessary and really helpful. So, yay statistics! (Student 8)

> You were able to connect to people, know them name by name, where normally you just see their user pop-up on discussion boards. There were a couple people that I would text outside of class, having met them in that virtual sense and say, "Hey, struggling on the homework, can you help me?". So, it was a lot more bonding. (Student 5)

> I think I had three or four people that we occasionally texted each other questions outside of Zoom, which was kind of nice, too, because then it was like bumping into your friend in the hall. (Student 8)

Another emerging theme found in students' responses to this question was that the sessions contributed to the students' positive perception of the course:

> I really liked the fact that we had groups. (Student 1)

> I had a really good experience with the course ... I thought statistics was really fun. I like the fact that it has more engagement. (Student 2)

> My experience with the team quizzes was a really positive one. Our professor had done a really nice job with setting up the formatting of the class to allow those class quizzes. Every time we were with different students and I think she did that intentionally, so that we wouldn't get comfortable or that one person would not carry a heavier load than others. That being said, it was fun. (Student 8)

Finally for this question, two students reported feelings of stress from trying to reach a team consensus for each quiz answer within the time allotted for the session:

> The pro is, you bounce some ideas, but ... there's that stress to come to an agreement. (Student 2)

> There's a little bit of a timeframe on getting the question, getting it right, getting it done. I think that there's a lot of different expectations going into a class by different people as far as how perfect and precise they need to be. (Student 3)

After this feedback, we asked students about time pressure during quizzes during all remaining interviews. No one else felt time pressure, but one student commented on the abundance of time. Interestingly, one interview conversation led us to ask about the student's perception of discussion boards, not used in our pedagogy, and the student was quite critical: "Those are so pointless. Every online class does them and they're the most pointless thing ever" (Student 7).

RQ2. How do students perceive the optional workbook (help) sessions?

To answer RQ2, we first asked students, "How helpful were these sessions for your learning of course content?". Most students responded that they did not attend, and some students reported that they watched the recordings. Students who attended valued being able to ask the instructor for help:

> I think the live workbook sessions were a lot of help ... I might be able to get 85% of the problem done, but I get stuck on this one spot ... And so they were pretty helpful for me. (Student 5)

> I think I would not have struggled initially in the beginning like I did, if I had attended them. (Student 6)

RQ3. What parts of the TBL learning sequence of activities were perceived as most and least helpful?

Our final research question did not yield much additional data. When we asked students which TBL learning activities were deemed most helpful and least helpful, students noted that the synchronous meetings and the workbook itself were most helpful. However, the answers varied widely with no trend for least helpful. In particular, Student 2 answered, "Any interaction I had with the teacher" was helpful, whereas Student 8 stated, "I want there to be a stats workbook for all of the classes".

When we asked students for suggestions for what to change in the course TBL learning sequence, they generally did not address aspects of the learning cycle but wanted increased opportunity to ask the instructor questions face to face and more direct video instruction. We also asked students to comment on their overall course experience, and students mentioned that they liked the course and would recommend their instructor to others. Interestingly, one student intended to pursue further education in statistics.

Table 3 below provides a summary of themes for the interview questions (all fall under one of the three initial guiding RQs).

Table 3
Student perceptions of team sessions, optional workbook sessions and the learning activity sequence

Sub-questions	Emerging themes
RQ1. What did you think about meeting synchronously for team quizzes?	• Students valued the real-time collaboration with peers and felt that the sessions contributed to their learning. • Some students were initially nervous about taking quizzes as a team, which resolved after the first session. Some felt time pressure to come to agreement during quiz sessions.
RQ1. Was this type of session different from other courses?	• Students compared team quiz sessions to team project work and appreciated that logistics were arranged by the instructor. • Students valued real-time instructor availability.
RQ1. What were your perceptions of interactions with other students?	• Students felt more connected to the class and peers; sessions gave students a social connection during a difficult time. • Synchronous interaction led some to form study groups.
RQ2. How helpful were these (optional) sessions for your learning of course content?	• Most students did not attend optional synchronous sessions. • Students who attended valued being able to ask questions live and would recommend these sessions to future students.
RQ2. How do these sessions compare to video instruction in other classes?	• Some students liked the question-driven video instruction, but others expressed they would prefer a more linear and organised presentation.
RQ3. Which learning activities were most and least helpful?	• Most helpful: The synchronous components and the workbook. • Least helpful: Answers varied.

Discussion

Findings suggest that regular synchronous semi-moderated sessions create a sense of belonging to the course and foster a sense of comfort asking questions. As detailed in the psychological literature, a sense of belonging and connectedness is recognised as essential by scholars to propel learning experiences (Rogers, 1985). According to Kim et al. (2020), psychological safety can drive team performance and enhance team processes and may lead students to show a higher level of help-seeking behaviour.

We believe that the students interviewed reported a high sense of belonging due to the meaningful peer interactions that they experienced during the synchronous sessions, along with just-in-time instructor assistance. Such findings are well aligned with the findings of Peacock et al. (2020) that interaction/engagement, the culture of the learning and support are crucial to promote a sense of belonging, which, in turn, is highly beneficial for online learning success.

Our results regarding student belonging were also likely influenced by the onset of the COVID-19 pandemic. Students may have had an unusually high level of appreciation for social interaction since they were abruptly unable to participate in other activities. Regular synchronous meetings provided a venue for students to connect and share their experiences and have access to the instructor for support. This suggests that this pedagogy may be particularly beneficial for students who lack a sense of belonging or feel disconnected from their peers.

This pedagogical approach was implemented in an effort to reduce high course failure and withdrawal rates. Since mathematical and statistical concepts are learned in a progressive fashion, students need an environment conducive to continued persistence. Students without persistence may be less patient with challenging problems, and sometimes declare themselves stuck and stop working. Without consistent support in a safe environment, they may withdraw into themselves and give up on the class altogether. Such withdrawal can swiftly occur in fully asynchronous online mathematics or statistics classes where just-in-time support is not always available.

Results suggest that the way the synchronous sessions were designed, implemented and moderated to mimic the RAP of TBL benefited student learning and may have helped some successfully complete the course. Scholars have identified technological struggles as a common barrier to participation in online learning. Such barriers are particularly evident in group work in an online learning environment (Gillett-Swan, 2017). To minimise technological difficulties, the instructors designed the course with Zoom meetings included. Moderation in this context includes, but is not limited to, arranging Zoom meetings for students, establishing expectations at the beginning of the course, providing clear instructions for teamwork during sessions and giving encouragement and assistance (Salmon, 2011).

Providing a common and well-defined goal for students to achieve during the meetings may have played an important role in motivating students and helping them focus on tasks. In effect, instructors should be active facilitators during synchronous sessions. Notably, the first quiz was designed to be part of the student buy-in process, having straightforward questions. This was recognised by Student 6:

> The first quiz, … [I thought] everyone should know this. It wasn't until things got really complicated in the semester that the team quizzes and stuff became a lot more helpful to me. I think the ones in the beginning are necessary to get the flow and develop.

Zoom breakout rooms initially have low social presence and low immediacy; students are working together without the presence of the instructor. The instructor purposefully designed achievable but challenging questions which provided a common goal for group members, which propelled active discussions (Tulis & Fullmer, 2013). The team quizzes provide immediate feedback, so that students know whether they need to further discuss concepts with peers to correct their thinking. The synchronous sessions helped students feel psychologically closer to each other and more likely to reach out when feeling stuck. Peer explanations in addition to the instructor's presentation of course content may have

contributed to an increase in student persistence in problem-solving, which correlates with improved mathematical reasoning skills (Andel et al., 2020).

If team members cannot help, instructors can intervene to provide just-in-time support. Importantly, the synchronous sessions provided regular access to such support. However, this is the last resort; students working in teams need to attempt to solve the problems themselves before seeking external help. Such a pedagogical method ensures regular instructor availability when students are stuck, and results suggest that this regular real-time interaction with the instructor for just-in-time teaching and encouragement contributes to student comfort in asking questions. In addition, the layering of different types formative feedback (Boström & Palm, 2023) helps students advance their learning.

Interviewing students after the course concluded ensured they had time to reflect on and process their perceptions of the effects of the course design on their learning and performance. However, since only student volunteers were interviewed, we are not able to generalise the results to all students. The time-bound nature of learning during the pandemic, often while relying on new delivery platforms and technology tools, undoubtedly impacted student perceptions of the pedagogy and their overall performance. In addition, it is likely that many of the students In this study as well as their friends and family members contracted COVID at some point during this study and thus were forced to deal with various health concerns.

Finally, our implementation of synchronous team sessions appears to work well for this course and population of students. However, students taking this course may not represent the general student population at the university. It is vital that instructors intending to implement a similar approach have a clear understanding of their teaching context and student population.

Implications

Findings from this study offer several implications for those planning to design and teach similar types of classes in an online environment.

First, this implementation of the TBL RAP preserves the real-time student-to-student interaction of the tRAT, which contributes to student sense of belonging and helps to advance their learning. But instructors must carefully consider how to schedule synchronous sessions for team quizzes, so that all students are able to attend. Both instructors in this study had prior experiences with students who unfortunately got stuck, did not feel safe or connected enough to ask them questions and had no peer network for collaboration. They adopted modified TBL in face-to-face courses to build collaborative teams for peer support and then sought these same benefits in their fully online courses. Both instructors indicated that they valued the synchronous online sessions which provided meaningful student-specific, just-in-time assistance and feedback even though moderating several synchronous sessions per week was time consuming. To compensate, other aspects of the course were optimised to ensure that instructors were not overwhelmed.

Second, some students may question meeting synchronously as part of a fully online course and hence may resist making the required scheduled time commitment. Trenholm et al. (2016) reported that mathematics faculty experienced student resistance when they incorporated or encouraged online synchronous collaborative work. In response, they suggested that the implementation of synchronous sessions as part of a fully online course requires further study. Accordingly, it is vital to document the potential causes of such resistance. We suggest informing students about synchronous components early, at registration if possible, and scheduling flexibility in available times as well as reasonable accommodations for students who cannot attend a session during a particular week. Bali (2016) advised considering time zones and family issues and setting session times that are convenient for all learners. We also suggest that instructors actively solicit student buy-in and clearly communicate the purpose of team quiz sessions, so that students see the connection between quiz sessions and their ability to succeed in the course.

Third, synchronous activities must be perceived by students as worth their time and effort. Sengupta-Irving and Agarwal (2017) showed how productive struggle can be constructed collectively within synchronous sessions to foster student persistence and an overall sense of community. Some students mentioned that they had "necessary and helpful" connections when working synchronously in teams. Productive struggle in teams when learning a new concept or connecting new ideas to prior knowledge gives students an opportunity to strengthen their knowledge base before working on applications that require critical thinking. Newman et al. (1995) found that verbal communication suits idea generation, while written communication formats encourage considered, well thought-out contributions. Therefore, placing synchronous verbal discussion early and written reflection later in the process is worth considering.

Fourth, it is likely that the success of the synchronous activity depends to some degree on the asynchronous course components, which were not discussed in detail in this paper. In fact, the findings suggest that synchronous TBL activities should not be implemented without careful consideration of how such an approach complements the overriding course pedagogy. The way that TBL is adapted and the decision about which components are conducted synchronously versus asynchronously can vary. Recent research by Parrish et al. (2021) on integrated online TBL reported student perceptions of effective components of the model.

Conclusion

The current study explored how students perceived synchronous team sessions in an introductory statistics course taught in an online environment. The synchronous sessions were carefully designed to promote collaboration and peer-teaching, and help students become independent learners as they progressed. As noted, most students were highly satisfied with the course and felt that team sessions contributed to their learning.

This pedagogical approach is comprehensive and systematic. The team quiz sessions were modelled on the RAP of TBL and promoted students' sense of community and comfort in asking questions. This in turn led to a safe learning environment and culture which is conducive to learning and may have contributed to student persistence in problem-solving and course completion. Meetings were highly structured and moderated by instructors, so that students knew what they were expected to accomplish.

Further research is needed to link such perceptions with student learning outcomes and course completion. As synchronous technologies continue to evolve and find value in higher education settings, the questions posed by this study will need to be revisited with appropriate refinements and adjustments. Replicated research efforts in different disciplines may generate different results and signal new opportunities.

Disclaimer

The opinions and assertions expressed herein are those of the author(s) and do not necessarily reflect the official policy or position of the Uniformed Services University or the Department of Defense.

Author contributions

Author 1: Conceptualisation, Investigation, Formal analysis, Project administration, Visualisation, Writing – original draft, Writing – review and editing; **Author 2**: Conceptualisation, Data curation, Investigation, Formal analysis, Methodology, Writing – original draft, Writing – review and editing; **Author 3**: Data curation, Investigation, Formal analysis, Writing – original draft, Writing – review and editing; **Author 4**: Conceptualisation, Formal analysis, Investigation, Visualisation; **Author 5**: Writing – review and editing.

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