Special Sections: Opportunities and Challenges of Online Instruction

JMBE Journal of Microbiology & Biology Education

Fidelity of Implementation as a Guiding Framework for Transitioning Research-Based Instructional Practices from On Site to Online

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In this Perspective, we contribute to the *Journal of Microbiology & Biology Education* special issue "Opportunities and Challenges of Online Instruction—Blurring the Lines Between Online and On-Site Teaching and Learning" by introducing a framework to guide instructors in transitioning from on-site to online instruction. The discipline-based education research community has produced a significant literature base demonstrating the effectiveness of various research-based instructional practices (RBIPs) that support student learning in face-to-face environments. However, little is known about how to transport these practices into the online environment. We introduce fidelity of implementation (FOI) as a framework for considering how to adapt RBIPs for online contexts while maintaining the integrity of the aspects of the practice that are thought to support student learning. We use our own experience responding to the global pandemic to provide rich examples of how FOI was used to anticipate challenges in transitioning online and describe how it was used to adapt an RBIP for online instruction.

KEYWORDS team-based learning, online instruction, biochemistry education, fidelity of implementation, remote instruction, student anxiety, inclusive teaching, instructor immediacy

INTRODUCTION

Scholars of discipline-based education research (DBER) have applied cognitive theories of learning and methodologies from psychology and the learning sciences to systematically investigate teaching and learning of undergraduate science, technology, engineering, and math (STEM) disciplines (1). This scholarship has resulted in the identification of many research-based instructional strategies (RBIPs) proven to support student learning (2–4). Most research underpinning these instructional strategies has been conducted in face-to-face (F2F) classrooms, but, as the global coronavirus disease 2019 (COVID-19) pandemic taught us, there is a need to understand how to effectively transport RBIPs into online environments. In this Perspective, we present fidelity of implementation (FOI) as a guiding framework for transitioning RBIPs from on site to online.

FOI is the degree to which an intervention or program is executed as intended and encompasses the idea that an intervention (i.e., an RBIP) has certain features essential to its effectiveness (5). The FOI literature refers to these features as critical components, which are characterized as either structural or instructional. Structural critical components reflect the intended design and organization of an intervention. For example, time for peer discussion and frequent low-stakes assessments are structural components of many RBIPs. Instructional critical components include ways in which participants are expected to behave or interact during the intervention. The expectation that students participate in peer discussion would be an instructional component. DBER scholars have shown that variations in how critical components are enacted can improve or diminish the outcomes of an intervention (6, 7). We build on this work to exemplify how FOI can be used to reflect on the critical components of an RBIP to (i) anticipate challenges in transitioning to online and (ii) identify productive adaptations to critical components to overcome these challenges. Given the brevity of Perspective pieces, we will limit our discussion here to the most pressing issues we faced as instructors transitioning a highly structured, team-based course to the online environment.

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The authors declare no conflict of interest.
Received: 14 December 2021, Accepted: 13 January 2022, Published: 30 March 2022

TEAM-BASED LEARNING (TBL)

TBL is an RBIP with documented benefits for student performance, engagement, and motivation (8–10). TBL emphasizes individual student preparation prior to class and application of

TABLE 1
Structural critical components of team-based learning

Structural critical component	Description
TBL norming session	Time is allocated for explaining TBL, setting expectations, and forming cohesive groups.
Preclass materials	Materials (e.g., readings, learning objectives, and prerecorded content) are provided for students to review prior to class.
Readiness assurance process (RAP)	Readiness assessment tests (RATs) are administered for individual (iRAT) and team (tRAT) completion. RATs assess key ideas from the preclass materials that will be applied in team exercises.
RAP appeals	An opportunity is provided for students to appeal their answers to the RAP.
Minilecture	Brief lecture or discussion to follow-up on misconceptions revealed by RAP or to extend on preclass material.
Team exercises	Assignments that require teams to apply concepts to solve disciplinarily meaningful problems are provided for teams.
Peer evaluations	Mechanism for peer evaluation is provided for students to provide feedback to teammates about the TBL experience.

knowledge through group work in class. At the start of a course, students are organized into diverse teams (5 to 7 students) that work together the entire semester. Before each course unit, students prepare for collaborative teamwork by reviewing instructor-assigned materials and completing a readiness assurance process (RAP), which involves completing a readiness assessment test (RAT) first individually (iRAT) and then again with their team (tRAT). Instructors then deliver a mini lecture to clarify misconceptions revealed during the RAP and extend on the concepts students will apply on team exercises that require them to collaborate on meaningful work in their discipline. Each of these structural components of TBL are well defined in the literature (8–10) (Table 1).

Effective implementation of TBL depends on several instructional critical components (Table 2) that are closely related to and often dependent on the structural components described above. To create a supportive environment for group work, instructors should explicitly encourage positive group behaviors and provide opportunities for students to reflect on their group dynamic and reinforce team bonds. Students should feel a sense of accountability to themselves and their teammates enough to review preclass materials and engage in the RAP before class. Instructors and students alike should provide frequent and timely feedback about the content, course, and group dynamics. These behaviors and interactions should ensure that teams are prepared and best able to leverage the strengths and develop the expertise of all team members.

ANTICIPATING CHALLENGES TO REMOTE IMPLEMENTATION OF TBL

Two of us (J.B.A. and E.G.O.) routinely use TBL in a two-semester biochemistry course cross-listed for upper-level undergraduates and graduate students. The course has an average enrollment of 50 to 70 students and is generally taught in an active learning classroom with tables instrumented with a computer. The global COVID-19 pandemic forced the majority of courses at Washington State University to move online, prompting us to consider how, if at all, we could continue using TBL. Through the lens of FOI, we first considered the structural critical components of TBL (Table 1) and were mostly concerned here with how to recreate the team-based environment. With an institutional license for Zoom, we could assign students to groups using breakout rooms. We also learned to leverage the Zoom infrastructure to provide informal feedback by moving between breakout rooms and encouraging student use of the "Ask for Help" button, mimicking how we as instructors would normally walk between groups and respond to team questions in the physical classroom. Additionally, many of our students were senior undergraduate and graduate students employed on campus or in surrounding areas, which meant only a few students needed to participate from other time zones. With these considerations, we did not expect the structural critical components to present much challenge in an online implementation of TBL.

In fact, we thought the structural components inherent to TBL may actually benefit students in the transition to remote instruction. Evidence from early in the COVID-19 pandemic suggested that students were experiencing decreased motivation due to a lack of structured time and changing schedules (11). One survey indicated that 45% of students were struggling with establishing a daily routine during the pandemic or were having logistical issues with online learning (12). This was true for many of our students who were in lockdown, experiencing disrupted schedules. We knew that highly structured active learning has been shown to increase student performance and reduce opportunity gaps and that predictable routines are considered "best-practice" for online environments (13–16). Thus, we anticipated that the predictable schedule of TBL activities each week (Fig. 1) would support student learning in the remote classroom.

TABLE 2
Instructional critical components of team-based learning

Instructional critical component	Description
Individual preparation	Individual students engage with preclass materials and iRAT prior to working with their team.
Team preparation	Teams of students negotiate agreement on the answers to the tRAT.
Appeal answers	Students make valid arguments appealing answers to questions that they got wrong.
Team interactions	Team members share resources and collaborate to solve team exercises.
Peer feedback	Students reflect on team interactions and provide feedback to teammates about what is and is not contributing to positive group processing.
Instructor feedback	Instructors provide frequent and actionable feedback to students throughout the TBL session.

Next, we considered the instructional critical components of TBL (Table 2). We suspected the remote environment, in addition to the global pandemic, might impact student behaviors and interactions expected in TBL. For instance, transitioning to online might increase student anxiety, which could affect team engagement and productivity. Fear of negative evaluation and unfamiliarity with teammates contribute to anxiety about group work in F2F classes (17) and could be further exacerbated in the online classroom where nonverbal cues are less prevalent and may have different meaning in Zoom than in F2F contexts (18). Nationally, students in all disciplines have experienced increased anxiety during the pandemic, especially students from vulnerable and marginalized populations (19, 20). Notably, in a survey of thousands of students during the COVID-19 pandemic, 37% of undergraduates and 32% of graduate and professional students screened positive for generalized anxiety disorder (19). Students who reported challenges in adapting to remote instruction were even more likely to experience generalized anxiety disorder (19). Further, with the increase in remote instruction during the pandemic, many universities expanded their subscriptions to online proctoring services. When coupled with high-stakes assessments, the use of proctoring software may increase already elevated levels of student anxiety, particularly for those students who identify with marginalized groups (21).

ADAPTATIONS TO THE CRITICAL COMPONENTS OF TBL IN RESPONSE TO ANTICIPATED CHALLENGES

The FOI framework allowed us to predict that the structural critical components of TBL would benefit students in online instruction but that higher anxiety may negatively impact the student behaviors and interactions necessary for effective TBL. In this section, we describe our adaptations to the critical components of TBL in response to the anticipated challenge of increased anxiety. Primarily, these could be considered adaptations to instructional critical components as they relate to our behaviors and interactions as instructors. Some adaptations also influenced structural critical components as they affected the opportunities available for student interactions.

In F2F instruction, we normally dedicate class time for students to become acquainted with one another, discuss expectations for communication, and develop a plan for maximizing productive group behaviors. During this introduction activity, students usually make name placards that include their name, pronouns, and a personal fact. Since physical name placards are impractical in Zoom, we explained how students could change in their screen names to include their preferred name and their pronouns. After introductions, students completed an activity where they discussed constructive and destructive group behaviors, identified their own constructive behaviors, and collaboratively created a plan to address destructive behaviors as a team when they arose (22). During this exercise we encouraged students to consider how the online environment might exacerbate destructive behaviors. As the semester progressed, we also reminded students to take turns sharing screens in Zoom so that no single student would be held accountable for entering answers for team activities.

As instructors, we were more intentional about engaging in behaviors associated with increased instructor immediacy (23), thereby reducing the perceived distance between ourselves and the students and reducing anxiety. We went in-depth when introducing ourselves to students, showing pictures of the places we grew up, introducing our family or pets, and talking about our backgrounds and education. We also played music before class to promote a positive atmosphere and invited song requests in the chat or over email to give students agency over what they heard while waiting for class to start. During these preclass periods, we played on repeat a slideshow created fresh each day with jokes, inspirational quotes, and practice "clicker-style" problems with feedback and explanations. We used appropriate humor, referencing biochemistry content occasionally, when including jokes on preclass slides (24).

We made explicit moves to elevate real stories of struggle and success in STEM, focusing particularly on traditionally excluded populations. Throughout the semester but especially during Women's History Month and Black History Month, we

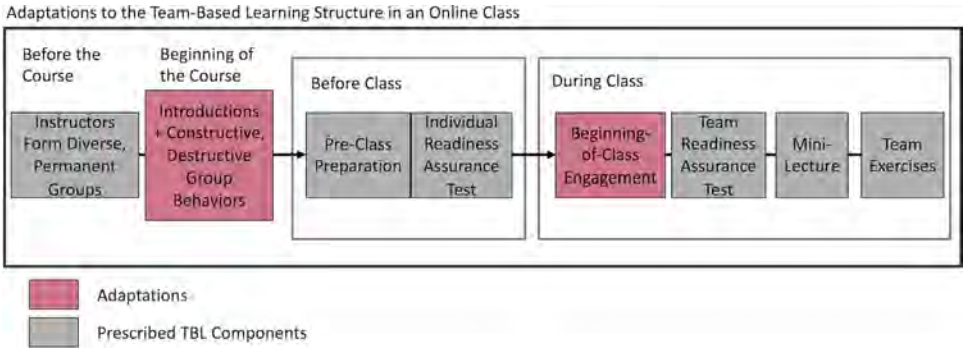

FIG 1. Adaptations to the team-based learning structure in an online class.

highlighted the work of women scientists, scientists of color, and members of the LGBTQ+ community on the preclass slides. We were also attentive to representing cases of intersectionality (e.g., women of marginalized race/ethnicity).

We also drew on the growth-mindset literature to craft language in the syllabus and in class emphasizing an intellectually curious and tolerant environment. Evidence suggests that these practices might help make courses more equitable for vulnerable and marginalized groups (25). We celebrated the diversity of the class, mentioning the different perspectives students would bring to biochemistry and how the teams' different backgrounds would help them learn.

Finally, we increased opportunities to provide students with feedback. In addition to the clicker-style questions, feedback, and explanations we provided on the preclass slides, we took advantage of the learning management system to program automated feedback on the team exercises. Teaching the students how to use the "Ask for Help" button built into Zoom also enabled us to quickly identify teams who were struggling and provide feedback to advance their work.

REFLECTIONS ON FOI AS A FRAMEWORK FOR TRANSITIONING TO REMOTE INSTRUCTION

In this Perspective, we have used our experiences during the global pandemic to explicate how we applied an FOI lens to transition from on-site to online instruction. Given the circumstances, we were unable to design a study to investigate the efficacy of our adaptations in terms of student learning. Yet, we did have access to anonymous student feedback that is gathered in the middle and end of every semester. Students were not prompted about specific aspects of TBL or anxiety but were asked generally about their favorite part of the course, what was not going well or should be changed, and anything else that was important for the instructor or university to know. In the online semester, an additional question was included regarding general difficulties associated with remote instruction. Since these surveys are routine course artifacts, the Washington State University Office of Research Assurances determined the project exempt from institutional review board (IRB) review.

To characterize how students experienced the F2F and online offerings of the course, all three authors developed and iteratively refined a descriptive coding scheme (26) to identify students' experiences, whether positive or negative, associated with the challenges we anticipated using FOI (e.g., TBL structure, student anxiety, group dynamics, and instructor immediacy). Two of us (J.B.A. and J.W.) applied the final coding scheme (Appendix 1) to all midterm and end-of-semester survey responses for both the online ($N = 38$, 54) and F2F semester ($N = 43$, 45). Once coded, we applied an interpretive lens to look across the descriptive coding and identify themes within and across semesters (26). In the remainder of this section, we present the themes from this systematic analysis of student feedback as an example of how instructors might reflect on their own efforts to transition between instructional environments.

Given the utility of the Zoom space, we did not anticipate that the structure of TBL would present much challenge in transitioning from F2F to online. Indeed, there were similar patterns in how students in both semesters explicitly commented on structural critical components (i.e., RAP, team exercises, and preclass materials), but there were also small differences in the frequency and types of comments. While students in both semesters predominantly mentioned group work (tRAT and team exercises) as helpful to their learning, we did notice that online students were twice as likely as F2F students to mention the benefits of iRATs and the preclass readings in helping them stay on top of the semester. However, online students were also more likely to report feeling pressured by the timed assessments in class.

This is not surprising; we anticipated student anxiety would be higher in the online environment and may negatively impact student interaction with TBL activities. In general, anxiety was mentioned more frequently by students in the online course. Yet, they were more likely to attribute their anxiety to external factors (e.g., COVID-19, work) and not to the structure or expectations of TBL. A few students in the online semester reported that the structure of TBL, in particular teamwork and frequent low-stakes assessments, actually helped reduce stress and motivate them. Similar comments were absent in the mid-semester and final course evaluations in the F2F course.

We also anticipated that the transition to online might present a challenge due to potential negative feelings about

working in groups. Examining students' self-reported experiences, we observed predominantly positive responses about working in teams in both the F2F and online versions. Moreover, the percentage of students reporting enjoyment of groupwork was similar between the two environments. We did, however, notice small differences in the frequency and types of negative comments provided by students. Seven students in the F2F semester reported negative group dynamics (e.g., conflict, unprepared team, and dominating teammates) on the midterm survey. By contrast, there were only two negative comments from students in the online environment. These comments did not explicitly mention discord as in the F2F semester; instead, one student reported feeling too dependent on the group at times, while the other suggested switching up groups after exams.

The main adaptation we made in transitioning online was to increase behaviors commonly associated with instructor immediacy (23). Students in both F2F and online environments frequently noted these behaviors in their midsemester and end-of-semester comments. When comparing across the two, there were no noticeable differences in frequency on midsemester surveys. However, on the end-of-semester course evaluation, several more students in the online environment explicitly referenced the instructional moves we implemented to increase immediacy.

CONCLUSIONS

In this Perspective, we presented FOI as a framework for transitioning RBIPs from on-site to online instruction. This was particularly important during the COVID-19 pandemic when we needed to transition rapidly to online instruction and, like many instructors across the nation, we had little institutional support or training to do so. FOI supported the transition without compromising the components of TBL that have been shown to support student learning. As online teaching of biology enters into a postpandemic world, instructors can similarly use FOI to critically evaluate their instructional design choices and more efficiently adapt aspects of F2F instruction for effective implementation in online environments.

FOI was also a productive framework for the systematic analysis of student feedback, providing a much-needed window into the student experience of TBL in the F2F and online environments. Student comments were generally similar, indicating that the transition of TBL to the online environment was largely successful. Yet, the more nuanced differences in student comments between the two semesters suggest that TBL and the adaptations we made helped mitigate the challenges we anticipated using FOI in our transition online. Despite seeming to experience more general anxiety, students in the online semester reported that aspects of TBL (e.g., individual RAP, frequent assessment, group work) were useful in motivating and preparing them to be successful within the course. By using FOI as a framework, we identified which critical components students noticed and why those components were perceived to contribute to their learning and engagement. For biology instructors moving more permanently into online environments, FOI may also be useful for systematically attending to student feedback. This may be particularly powerful for instructors if paired with reflection on student performance data, thereby facilitating more fine-tuned adjustments to the critical components of RBIPs to best support student learning online.

SUPPLEMENTAL MATERIAL

Supplemental material is available online only.

SUPPLEMENTAL FILE 1, PDF file, 0.3 MB.

ACKNOWLEDGMENTS

This work was supported in part by an NSF GRFP award (1842493).

We declare no conflicts of interest.

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