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Teamwork Makes the Dream Work: Using Team-Based Learning in the Science Classroom

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With an overwhelming amount of research and a demand for collaborative learning in the classroom, teachers are tackling challenges at all educational levels that often accompany the social aspects of group work. Team-Based Learning (TBL) is an instructional sequence that shifts instruction from teacher lecture to small-group learning. Through the use of teams and social learning, students are actively engaged and learning through critical-thinking tasks. College students can take responsibility both for their own learning and for each other as learners and fellow human beings. TBL allows the instructors to design opportunities for students to demonstrate what they know and can do in the classroom with the content. This study qualitatively examines students' perceptions of the pedagogical strategy TBL in an undergraduate science course. TBL practices enabled instructors to prepare students for classes in advance and assist students in deeply learning the material through application of course concepts, allowing them to solve interesting, complex, and real-world problems that are relevant to the teaching profession.

According to the K–12 *Next Generation Science Standards* (*NGSS*; NGSS Lead States, 2013), the United States needs workers with strong backgrounds in the fields of science, technology, and engineering. With rapid advances in technology and science education, it is imperative educators produce citizens who are competitive in the U.S. workforce (NGSS Lead States, 2013). The *NGSS* emphasize that all citizens need science, technology, engineering, and mathematics (STEM) practices (NGSS Lead States, 2013). Often, educators require STEM practices only with students pursuing a career in science or mathematics; however, our world revolves around STEM. For students to become scientifically literate citizens in our society, all students need to use STEM practices in the classroom to promote student learning (NGSS Lead States, 2013). There is a significant need to improve science education across the United States, and it is critical that instructors use the most effective pedagogical strategies in the classroom with all students.

Team-Based Learning

Science educators at all levels of education use a variety of pedagogies to promote higher levels of student self-efficacy and scientific literacy. One pedagogical strategy many teachers are exploring is Team-Based Learning (TBL). Sibley and Ostafichuk (2014) described TBL as "an extraordinary form of small-group learning—both effective and fun" (p. 3). TBL transforms educators and students by bringing "more fun, energy, and deep learning to the classroom" (Sibley & Ostafichuk, 2014, p. 3). TBL promotes cognitive gains at all educational levels. In P–12 settings, TBL can be used when integrating other content areas. For example, the publication *Social Studies for the Next Generation* (National Council of Social Studies [NCSS], 2013) stresses how students must construct compelling questions to initiate inquiry through collaboration with others. TBL "supports students as they develop the capacity to know, analyze, explain, and argue about the interdisciplinary challenges in our social world" (NCSS, 2013, p. 6). In addition, using TBL at the collegiate level allows students to collaboratively apply knowledge within the disciplines of STEM as they "develop questions and plan inquiries; apply disciplinary concepts and tools; evaluate and use evidence; and communicate conclusions and take informed action" (NCSS, 2013, p. 6).

The TBL strategy was developed by Larry Michaelson to incorporate collaborative learning in a large class environment (Parmelee, Michaelsen, Cook, & Hudes, 2012). TBL was first developed for the business school setting, but the strategy has been used at various educational levels and programs (Parmelee et al., 2012). TBL shifts instruction from traditional, teacher-centered lectures to student-centered, active learning using critical-thinking tasks that promote problem-solving (Wanzek et al., 2015). There are "four practical elements of TBL (1) Strategically Formed, Permanent Teams, (2) Readiness Assurance, (3) Application Activities and (4) Peer Evaluation" (Michaelsen & Sweet, 2011, p. 41).

The purpose of this qualitative study was to investigate students' perceptions of TBL at the collegiate level with nonbiology major undergraduate students enrolled in a general Biology II course. The research question guiding the study was: How do college students perceive the use of TBL in a General Biology II course? We discuss in more detail the key elements of TBL and how these were implemented throughout the semester from August until December in a General Biology II course.

Strategically formed, permanent teams

At the beginning of the semester, the instructor assigned permanent teams for the TBL students enrolled in the General Biology II course. Researchers referenced Wanzek et al. (2015) and diversely distributed students in teams based on skills such as "temperament, participation disposition, motivation, and general academic excellence" (p. 332). Initially, during the first class meeting, students chose to be seated by friends, but the instructor strategically formed four diverse groups. Team groups were required to remain consistent for the duration of

TABLE 1

Module one of General Biology II course: Taxonomy and viruses.

Week	Topic	Date	In-class activities
1	Taxonomy	8/23	**RAP process:** • Students complete iRAT (10 multiple-choice question quiz) individually. Questions are based on the preparatory reading materials assigned to students prior to the module. • Students will complete the iRAT and work in teams to complete the tRAT (10 multiple-choice questions; quiz identical to the iRAT) using one scratch card per team. **Mini lecture:** Instructor will answer student questions and conduct a brief discussion about the material from the iRAT/tRAT.
		8/25	**Case study:** Student teams will complete "An Antipodal Mystery Case Study" (Herreid, 2005). This interrupted case study explores the process scientists use to classify new organisms by following the difficult task scientists encountered when trying to classify the platypus. This case is presented in four parts; after each part, students will discuss how they think the platypus should be classified based on given information. This case demonstrates the nature of science and how scientific ideas/opinions are constantly changing over time as new information emerges.
2	Viruses	8/29	**Case study:** Student teams will complete "A Case Study Involving Influenza and the Influenza Vaccine" (Bennet, 2008). This interrupted five-part case allows students to understand the benefits of vaccination while also learning general characteristics of viruses.
		8/31	**Review:** The instructor will review material from the two case studies and answer any student questions related to the topics.

Note: Both case studies were retrieved from the National Center for Case Study Teaching in Science (2017; http://sciencecases.lib.buffalo.edu/cs).

the semester in hopes of achieving a sense of cohesiveness and team pride.

Readiness assurance

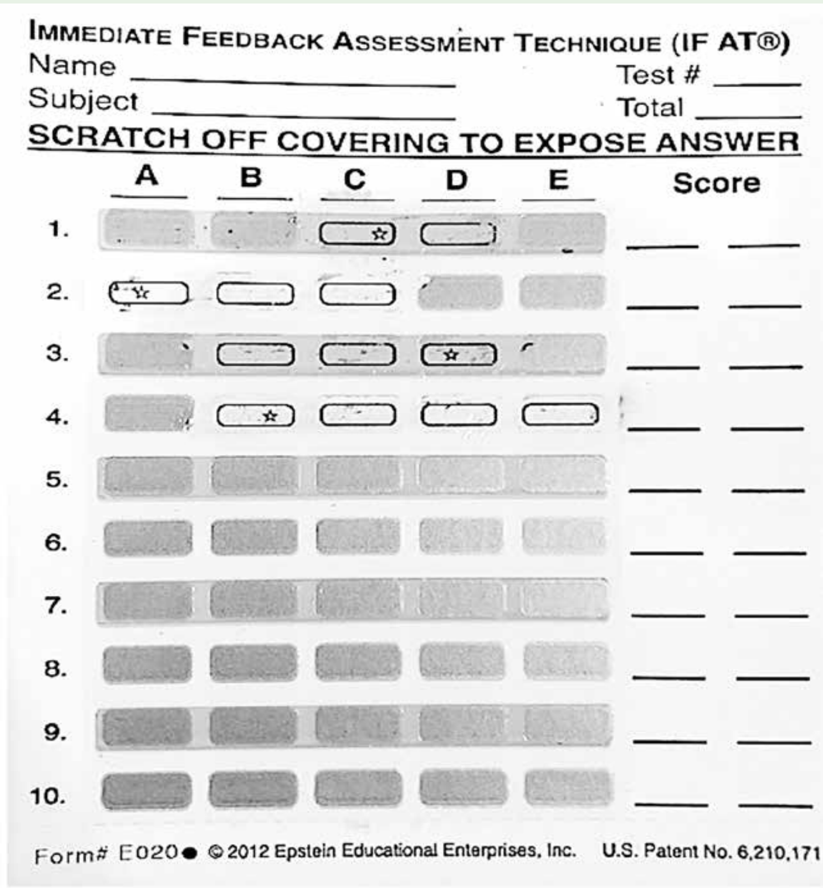
Sibley and Ostafichuk (2014) recommend dividing the TBL material into modules, each following a 2-week instructional sequence. The researchers created the General Biology II course schedule to include six modules by dividing content from the nine chapters in the textbook *Biology: Concepts and Investigations* (Hoefnagels, 2015) and incorporating case studies from the National Center for Case Study Teaching in Science (2017). An example of one module from the course schedule is presented in Table 1. Researchers continued to follow Sibley and Ostafichuk (2014) and assigned readings or other preparatory materials such as newspaper articles, journal articles, textbook chapters, podcasts, PowerPoint slides, or instructional videos prior to the beginning of each new module.

During the first class meeting of each new module, the instructor used the Readiness Assurance Process (RAP). This two-part process involved using an Individual Readiness Assurance Test (iRAT), and a Team Readiness Assurance Test (tRAT). The iRAT required students to individually answer and turn in a brief set of questions over the assigned reading material. Following the iRAT, teams collaboratively took the tRAT that had duplicated questions from the iRAT. During the tRAT, teams answered the questions using the Immediate Feedback Assessment Technique (IF-AT) Scratch Cards as shown in Figure 1 (Epstein, 2016). The correct answer was denoted with a star on the Scratch Card. For each incorrect answer, points were deducted from the tRAT total score. The Scratch Cards allowed teams to discuss each question to promote a spirit of collaboration and allowed immediate feedback leading to a higher retention rate (Epstein et al., 2002). Researchers found the IF-AT method "actively engages the learner in the discovery process and this engagement promotes retention through the correction of initially inaccurate response strategies" (Epstein et al., 2002, p. 187).

Following the RAP process, the instructor discussed the questions and provided a brief minilecture to review difficult concepts (Sibley & Ostafichuk, 2014). The RAP saved valuable class time that would normally be used as lecture time for students. The RAP also allowed students to actually wrestle with the material and gain a deeper understanding of the topics and concepts (Sibley & Ostafichuk, 2014). The scores of the RAP from the first module revealed

FIGURE 1

Immediate Feedback Assessment Technique (IF-AT) scratch card. Correct answer is indicated by star. Students work in teams to scratch answer choices until they receive a correct answer. Each question is worth a total of 10 points. For every incorrect scratch, two points are deducted.



that many students had not read the preparatory material prior to coming to class. In the subsequent modules many students reviewed and studied the preparatory material in advance before taking the RAP, enabling scores to improve. Initially, during the tRAT portion of the RAP, most teams typically used the majority rule to choose answers. Sibley and Ostafichuk (2014) found that "in early Readiness Assurance testing, student teams use simple votes on split decisions and let the majority rule" (p. 11). They concluded, "As team members found their social feet within the team and team cohesion began to increase with each testing cycle, the decision-making process progressively became more consensus-based" (p. 11). Researchers noted in this study that as the semester progressed, students were more consensus-based with each new module as well.

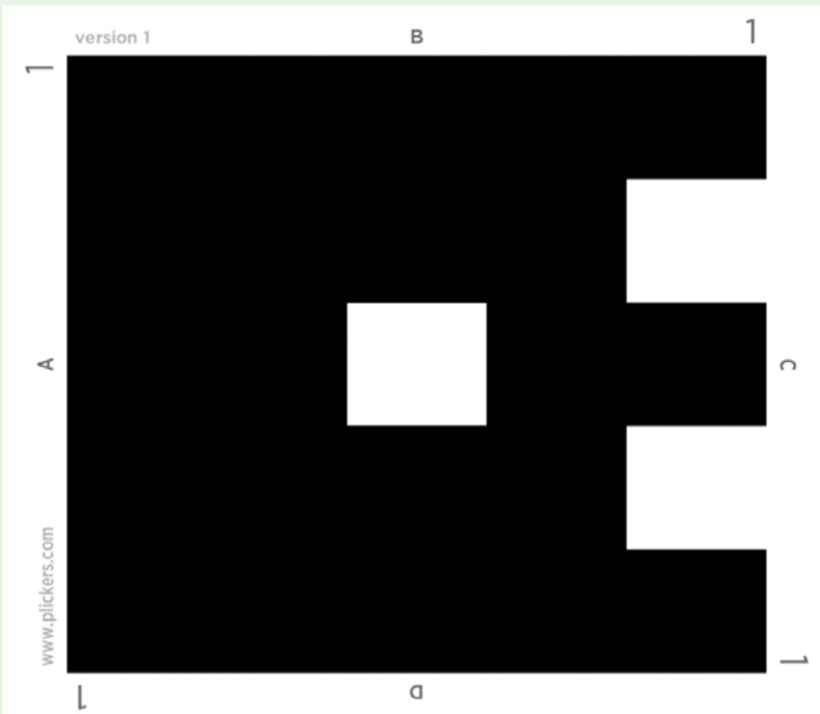
Application activities

According to Michelsen and Sweet (2011), the next practical element of TBL requires students to apply foundational knowledge gained in the RAP process to an Application Activity (p. 41). Case studies, vignettes, or other real-world, critical-thinking tasks were given to students as Application Activities (Sibley & Parmelee, 2008). The TBL Application Activities allowed students to have many performance accomplishments throughout the course, unlike traditional teaching strategies in which students only "perform" on written tests.

For the application activities to work best, researchers Michelsen and Sweet (2011) advised following the 4-S Strategy (p. 45–46). The 4-S Strategy includes: (1) Significant Problem, (2) Specific Choice, (3) Same Problem, and (4) Simultaneously Report. Each team completed the 4-S Strategy by first identifying the Significant Problem that addressed the topic's relevance and related the problem to students' future careers or personal lives. Second, teams made a Specific Choice by respectfully debating to reach a consensus on one group answer. Many times answers included phrases such as: most important, most correct, and best example. Specific Choice allowed students to "accomplish the task by working together to critically appraise a situation, examine the existing evidence, and make a professional judgment" (Parmelee & Michaelsen, 2010, p. 120). Third, Same Problem required all teams in the class to be provided with the same problem at one specific time (Epstein, 2016). Last, students were required to Simultaneously Report answers once the task is completed and followed by a whole-class dis-

FIGURE 2

Plicker card for one student/team. This card was obtained from the Plickers website (https://help.plickers.com/hc/en-us/articles/360008948034-Get-Plickers-Cards). Cards are free on this website. Each Plicker has a unique shape that can be read by the instructor's smartphone Plicker application. The numbers located around each corner correlate with individual students or teams. The letters on each side of the square represent different answer choices. For students to present their answer choice, they simply hold the Plicker card with the selected answer choice at the top for the instructor to scan with a smartphone.



cussion where students report answers publicly (Epstein, 2016). Parmelee and Michaelsen (2010) discussed the importance of all the teams simultaneously reporting to create a "moment of truth" situation. Through this process, two critical aspects emerged from TBL that included team cohesiveness and answer justification as classmates challenged and presented answers publicly (Parmelee & Michaelsen, 2010).

Peer-reviewed case studies from the National Center for Case Study Teaching in Science (2017) are primarily used during the Application Activities. According to the National Center for Case Study Teaching in Science (2017), the mission is to promote the nationwide application of active learning techniques to the teaching of science, with a particular emphasis on case studies and problem-based learning. The case studies are offered in numerous formats, including the *interrupted case study* where students are provided increasing amounts of information for discussion at intervals throughout the case study.

The National Center for Case Study Teaching in Science (2017) also includes clicker case studies and uses interactive Microsoft PowerPoints to engage students through an installed clicker system. Plickers (https://www.plickers.com) are a free alternative to expensive clicker systems. An example Plicker card is shown in Figure 2. Plickers include multiple-choice cards printed from a website with a unique four-sided shape with answer choices A–D on each side. Each team received a Plicker, and throughout the case study researchers created multiple-choice questions to correlate with the case studies from the National Center for Case Study Teaching in Science. The teams simultaneously voted on a specific answer. The instructor downloaded the free Plicker application on a smartphone that used the phone's camera to scan the room. The Plicker website receives the live feed from the application, allowing the instructor and students to receive immediate formative feedback when answer choices were projected. Teams became more cohesive

TABLE 2

Peer evaluation rubric.

Team member name:____________________
Instructions: Use this rubric to evaluate each of your team members on performance in team assignments and activities completed throughout the course.

Criteria	**0 points**	**5 points**	**10 points**	**15 points**	**Total points**
RAP process	Never prepared for the iRAT/tRATs and made no contributions to team discussions during the tRAT.	Rarely prepared for the iRAT and tRATs; made few contributions to team discussions during tRAT.	Sometimes prepared for iRAT/tRAT; Made some contributions to team discussions during tRAT.	Always prepared for iRAT/tRAT; always made contributions to team discussions during tRAT.	Score____
Application activity contributions	Never contributes to team discussions during case studies or other application activities.	Rarely contributes to team discussions during case studies or other application activities.	Almost always contributes to team discussions during case studies or other application activities.	Always contributes to team discussions during case studies or other application activities.	Score____
Collaboration/ teamwork skills	Never or rarely demonstrates a positive attitude and respect toward others while never working toward team goals.	Almost always demonstrates a positive attitude and is respectful of others while rarely working toward team goals.	Demonstrates a positive attitude and is respectful of others while sometimes working toward team goals.	Demonstrates a positive attitude and respectful to others while actively working to motivate, encourage, and accomplish team goals.	Score____
	Total score =______/45				

with the implementation of the case studies from the National Center for Case Study Teaching in Science and Plickers through each module as the semester progressed.

A sense of team spirit emerged after completion of Application Activities and many groups respectfully competed with other teams in the class. Throughout the semester, the students addressed common misconceptions about content and certain topics through the application activities. The most effective questions in promoting student learning were the Specific Choice questions that allowed teams to debate and critically analyze the questions more so than the open-ended questions. With the open-ended questions, many team members passively observed and approved as one member wrote the entire answer. The Specific Choice questions enabled all students to participate and reach a consensus on a specific choice. In addition, the Application Activities involving Plickers and case studies allowed all students to gain ownership of the learning material.

Michaelsen and Sweet (2011) discussed the fourth practical element of TBL that included peer evaluation to hold students accountable throughout the course. Students receive both formative and summative feedback from teammates about contributions to the team and its success. Parmelee and Michaelsen (2010) stated "a well-designed peer evaluation process enables students to learn how to give constructive feedback to one another and to gratefully receive constructive feedback from peers—an invaluable competency for future practice" (p. 121–122). In the General Biology II course, peer evaluation was administered alongside the midterm and the final exam by using a rubric as shown in Table 2. In the TBL treatment section, peer evaluation was administered alongside the midterm and the final exam by using a rubric. This allowed team members to assess each other's collaboration, cooperation, and teamwork skills by holding all team members accountable.

TABLE 3

Evaluation of assessments for General Biology II course using the Team-Based Learning strategy.

Assessment	Weighted percentage
Individual Readiness Assurance Test (iRAT) average	5
Team Readiness Assurance Test (tRAT) average	5
Case studies/application activities average	20
Peer evaluation average	10
Midterm exam	30
Comprehensive final exam	30

Methods

This study explored how students perceived TBL implementation at the college level. A qualitative case study design was employed to develop a deeper understanding of the use of the TBL strategy and perception of learning in teams at the collegiate level (Yin, 2014). Case-study designs are appropriate when there is a lack of in-depth understanding of a phenomena and a need to analyze unexplored details in order to inform practice (Creswell, 2009). The unit of analysis for the study was the participants included in the non-major General Biology II students from a private college in a small, rural community in the southern United States. A total of 20 participants were enrolled in the course, including 9 females and 11 males, most of which were primarily traditionally aged freshman being 17 or 18 years old.

The general Biology II course is an introduction to basic biology principles and includes the Domains of Life Biological Classification System. The evaluation of assessments used in the course can be seen in Table 3. Generally, students who elect to take this course are not planning on pursuing a biology-related degree. Field notes were taken by the researchers at various times during the semester and at the end of the course students completed a Student Questionnaire. The Student Questionnaires were then coded for themes that related to the "four practical elements of TBL, which included: (1) Strategically Formed, Permanent Teams, (2) Readiness Assurance, (3) Application Activities and (4) Peer Evaluation" (Michaelsen & Sweet, 2011, p. 41).

Data collection

A Student Questionnaire was administered at the end of the semester to students in the TBL section. The Student Questionnaire included the following questions:

1. What is one thing you did not like about the Team-Based Learning strategy employed in this class?
2. What is one thing you liked about

the Team-Based Learning strategy employed in this class?
3. Is there anything else you would like to share about your experience with Team-Based Learning?

Students completed the questionnaire anonymously.

Data analysis

A constant comparative (Strauss & Corbin, 1990) approach was used to analyze the data. The Student Questionnaires were read and coded for themes. First, the data were read and analyzed separately. As codes emerged, we compared them with the previous incidents that coded in the same category to find common patterns as well as differences in the data (as in Glaser, 1965). Categories emerging from the data were exhaustive, mutually exclusive, sensitizing, and conceptually congruent and reflected the purpose of the study (Merriam, 1998). To address issues with validity and interpretation, two researchers coded the data separately and then compared coding to come to 100% agreement on the coding.

Results

The Student Questionnaire revealed the effectiveness of peer evaluation. The RAP assessments included the iRAT and the tRAT and were not heavily weighted when compared with other assessments in the course; however, students were very concerned when performance was low on these assessments. One student commented, "If you were not prepared one day, your team could give you a bad grade and say you did not contribute throughout the semester." Many students asked for additional help after completion of the RAP and wanted to review difficult content and this was a desirable result in that students took ownership of the learning at the very beginning of each module. The instructor thought peer evaluation motivated students to prepare and contribute with other group members during all class meetings. One student comment included the importance of holding each team member accountable by stating, "If classmates did not help hold up their side of the bargain, it made it harder on the rest of us."

The Student Questionnaires were then coded for themes that related to "four practical elements of TBL (1) Strategically Formed, Permanent Teams, (2) Readiness Assurance, (3) Application Activities, and (4) Peer Evaluation" (Michaelsen & Sweet, 2011, p. 41). The first theme regarded students' dissatisfaction with the lack of lecture. The second theme noted was group dynamic problems. The third theme that emerged was students enjoyed collaborating with group members with the active learning strategy of the TBL treatment.

Lecture

Students (n = 9) noted dissatisfaction with the lack of lecture and did not feel prepared for the RAP stage of TBL. Students desired for the material for each module to be entirely covered by the instructor and did not like to take ownership of independent learning. Therefore, some students expressed frustration as a result of preparatory material never being formally introduced prior to the RAP during the course session. One student comment stated, "There was not much lecture or review, which would have been helpful." Another comment stated, "I like it! The only modification could be adding a little bit of lecture or review with visuals such as PowerPoints." These comments are representative of those students who felt this way.

Though some students (n = 9) desired more lecture time in the class, one goal of the TBL strategy is to hold students accountable for individual learning. A mini-lecture was held after every RAP and could last as long as students posed questions related to the content. The instructor noted that many students did not pose questions because they did not complete the preparatory reading material. The instructor was pleased when grades of the RAP improved over the semester and noted students were adequately preparing for each module. Over the semester, in the field notes the instructor recorded improvements in the minilectures of the RAP. Students began bringing questions about the material to class sessions, transforming passive lectures of the past into active interactions between students and instructor.

Traditional, full-class lectures became more productive through brief, purposeful lectures based around student questions after the RAP. This allowed additional time to devote to critical-thinking application tasks. One implication of TBL was the ability to actively engage students through a spirit of collaboration, improving student understanding of complex material. The Student Questionnaire revealed that the case studies offered during the Application Activities enabled students to apply foundational knowledge and students were actively learning as opposed to passively listening to a lecture. For example, one student said, "I enjoyed getting to actively learn and not just sit still and quiet."

Group dynamics

Grouping dynamic problems were the second theme that emerged from the Student Questionnaire. Students (n = 3) reported that some teams did not work well together because of personality differences. Also, some students (n = 2) reported only one or two individuals carried the weight of the team. Another representative comment (n = 1) regarding teamwork included, "Most of the time we were responsible for only one aspect of the assigned activities, leading to partial learning of the content."

Other comments (n = 14) revealed positive student perceptions toward teamwork through the TBL course. Many desired results about team cohesiveness were noted by the researchers about the TBL approach. One student stated, "I liked the way the class was set up. I liked working together, bouncing ideas off others, and working in teams, enabling me to make new friends and learn in a new way." In addition, others (n = 11) thought the TBL course allowed chances to complete complicated coursework with others.

Collaboration

The TBL strategy improved students' collaboration skills. For example, one student demonstrated collaborative growth commenting, "It taught me to be patient with others." Another student noted, "We got to solve the problems as a team and it was better to have four brains with different ideas and opinions because it led us closer to the answer." Another student stated, "Always having other opinions helps you think better and come up with better solutions."

Conclusion

Overall, the Student Questionnaire coding results showed positive comments about the TBL approach. Based on the findings of the researchers, the active learning of TBL proved to be a powerful pedagogy. The various forms of instruction throughout each module included individual and group assessments, mini case studies, peer evaluation, and immediate feedback techniques such as Plickers and IF-AT scratch cards. TBL can be introduced with relatively small changes to the course structure and offer an effective means to increase student engagement. The TBL pedagogy helps to move students beyond information gathering as a primary takeaway from class to apply content to the real world. Until science instructors are able to convert lecture-heavy content courses into more active learning environments, students will continue to struggle with collaboration, which is imperative in preparing students to become more scientifically literate and competitive in the U.S. workforce. ■

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