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Making students do the thinking: team-based learning in a laboratory course

Shawn R. Simonson
Department of Kinesiology, Boise State University, Boise, Idaho

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Simonson SR. Making students do the thinking: team-based learning in a laboratory course. *Adv Physiol Educ* 38: 49–55, 2014; doi:10.1152/advan.00108.2013.—Team-based learning (TBL) is a teaching pedagogy for flipping the classroom that moves the focus of the classroom from the instructor conveying course concepts via lecture to the application of concepts by student teams. It has been used extensively in lecture courses; however, there is little evidence of its use in laboratory courses. The purpose of this report is to describe the implementation of TBL in a graduate exercise physiology laboratory course. Using TBL in a graduate laboratory course was very successful and well received by both the students and instructor. Students reported increased content learning, skill development, and retention. They took on the responsibility for learning and were more accountable. The learners drove the process and were guided by the instructor rather than through instructor-centered delivery.

team-based learning; flipping the classroom; student-centered teaching

TEAM-BASED LEARNING (TBL) is a teaching pedagogy for flipping the classroom that moves the focus of the classroom from the instructor conveying course concepts via lecture to the application of concepts by student teams (3). In the TBL process, students acquire their initial exposure to the content through readings and are held accountable for their preparation using a readiness assurance process (RAP). After the RAP, the bulk of class time is used to practice applying content in a series of team application exercises.

TBL requires that instructors shift their paradigms: *1*) the course goal shifts from knowing content to applying concepts, *2*) the instructor shifts from delivering information to creating opportunities that will engage students in learning, *3*) students shift from passive to active participants, and *4*) the responsibility for learning shifts from the instructor to the student (3).

There are four essential elements of TBL: *1*) student teams (teams are carefully formed and managed), *2*) accountability (individuals are accountable for both their individual work and the quality of the teamwork), *3*) feedback (feedback is frequent and timely), and *4*) assignment design (team assignments encourage learning, concept application, and teamwork) (1).

A TBL course is generally broken up into units or modules that require 1–3 wk to complete. The unit begins with students completing readings before attending class and then participating in the RAP on the first class day of the unit. The RAP consists of a short individual test, the same test taken as a team with immediate feedback, the opportunity to appeal test questions, and then clarification of still difficult material. After the RAP, the remainder of the module is spent applying the content in class to questions or problems via activities and case studies (2, 3).

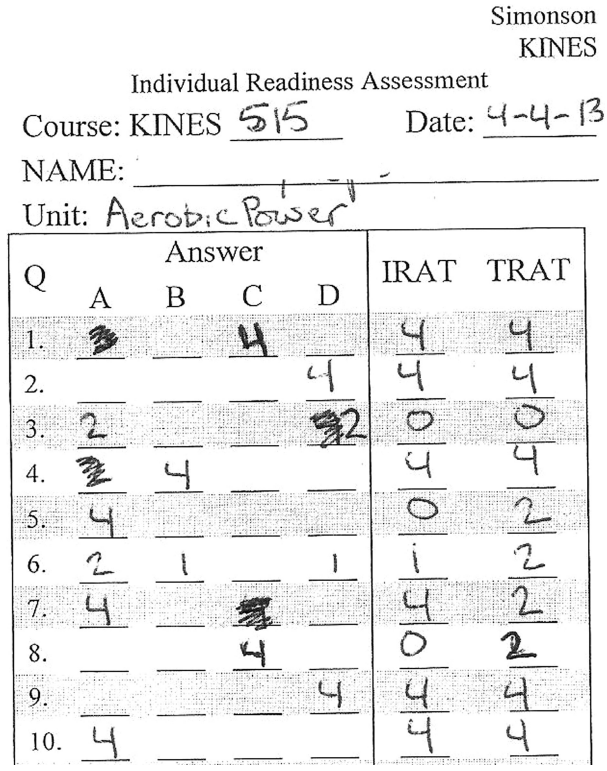
Address for reprint requests and other correspondence: S. R. Simonson, Dept. of Kinesiology, Boise State Univ., 1910 University Dr., Boise, ID 83725-1710 (e-mail: shawnsimonson@boisestate.edu).

RAP

The RAP is a two-step process consisting of readiness assurance tests (RATs): *1*) students take an individual RAT (iRAT), which is a short multiple-choice test, and then *2*) student teams take the same RAT together (tRAT) (1). RATs are based on assigned readings and cover the concepts to be applied in class. The same RAT is given to individuals and teams; therefore, students earn two grades (individual and team) for each RAT. If students miss a RAT, they receive the team score for the tRAT. There are options for their iRAT: *1*) take the test early, *2*) take the test later, *3*) drop the lowest score, or *4*) substitute the score on the final exam for the missing iRAT.

The iRAT form (Fig. 1) allows students to weight their confidence in their answer. Each question is worth four points, and students assign a total of four points on each line of the answer sheet. Their score is the number of points assigned to the cell that corresponds to the correct answer. Answer sheets are marked in ink.

The tRAT form is the immediate feedback assessment technique (Epstein Educational Enterprises, Cincinnati, OH; Fig. 2), which provides students with feedback about the correctness of their answers as they take the test. After deciding on an answer as a team, one team member scratches off the


Simonson
KINES

Individual Readiness Assessment

Course: KINES 515 Date: 4-4-13

NAME:

Unit: Aerobic Power

Q	Answer A	B	C	D	IRAT	TRAT
1.	3		4		4	4
2.				4	4	4
3.	2			2	0	0
4.	3	4			4	4
5.	4				0	2
6.	2	1		1	1	2
7.	4		3		4	2
8.			4		0	2
9.				4	4	4
10.	4				4	4

Fig. 1. The individual readiness assurance test form.

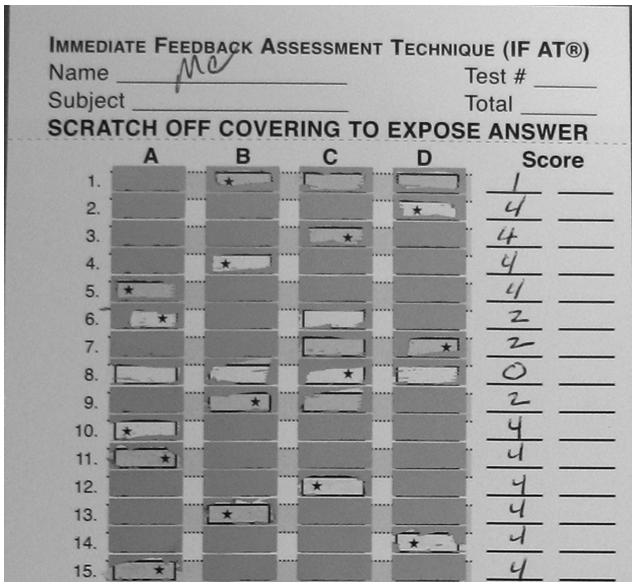


Fig. 2. The immediate feedback assessment technique (IF-AT; Epstein Educational Enterprises, Cincinnati, OH) form.

covering to see if they are correct. If at first they do not succeed, they try again. The test is scored as follows:

- One scratch = four points
- Two scratches = two points
- Three scratches = one point
- Four scratches = zero points

Each team member then records the number of points earned before going on to the next question.

After completion of the tRAT, the scores are totaled and the answer sheets are turned in. Teams may then appeal any question with which they disagree. The appeals process helps teams clarify uncertainty about understanding of the concepts and gives additional recognition and credit when "missing" a question was caused by ambiguity in the reading material, disagreement between the reading material and the "correct" answer, and ambiguity in the wording of the question. Some instructors allow the appeal process to proceed immediately after the RAP; others require teams to write appeals after class or after the material has been reviewed in class. Appeals are granted when students demonstrate that they understood the concept(s) but missed the question anyway or that their confusion was due to inadequacies in either the question or the reading material.

If the appeal is based on ambiguity in the question, teams must identify the source of ambiguity in the question and offer an alternative wording that would have helped them avoid the problem. If the appeal is based on either inadequacies in the reading material or disagreement with the answer, teams must state the reason(s) for disagreeing with the answer and provide specific references from the reading material to support their point of view.

When an appeal is accepted on a question that a team has missed (no individual appeals), it "counts," i.e., the points missed will be added to their team score, the score of any individual who answered the same way as the team, and only those teams who appeal. Team member(s) who had the "original" correct answer will continue to receive credit on the question.

Upon completion of the appeals process, the concepts are discussed as a class. However, only those concepts that students did not demonstrate an understanding of are covered. Two questions are asked, and the answers to these questions determine which concepts will be covered via class discussion or a minilecture: *1*) which questions did the majority of teams have trouble with and *2*) which questions would students like the instructor to discuss.

The RAP is shown in Fig. 3.

After the completion of concept clarification, students are presented with problems/cases that allow them to apply the concepts just covered. There are four keys ("4Ss") that can improve the effectiveness of the cases (2); these are as follows:

1. Significant (problems that truly demonstrate the concepts and their application)

2. Same (all teams work on the same problem)

3. Specific choice (concepts are used to make a specific decision about the problem)

4. Simultaneously report (all teams report their choice at the same time using a response system, posters, or some other format)

Grading Requirements and Procedures

Student ownership in the grading process is promoted by allowing the teams to set grade weights during the first class meeting. Minimal grading weights are provided for *1*) individual performance, *2*) team performance, and *3*) team contribution. The types of assignments making up each of these three categories are listed, and the minimum weights are indicated. Teams discuss how they would like to assign grade weighting to each category and the assignments within that category. Representatives of each team then determine grade weights for the class. Final grades are determined using this weighting system. While instructors might set various limitations, the limitations on grade weight decisions in this implementation of TBL were *1*) a minimum of 10% of the total grade must be assigned to each major performance area, with the individual contribution counting for at least 50% of the course grade; and

Individual Test*	**Team Test****	**Appeals*****	**Questions/Discussion**
Mark both tests and answer sheet (4 points per line)	Use IF-AT answer sheet (closed book)	Open book (starting when team score is posted)	"Which questions did the majority of teams have trouble with?"
Name and team number on test and answer sheet	Record score for EACH question (helps with appeals)	Base appeals on evidence from readings	"Which questions would you like me to discuss?"
Answer sheets in folder and turn in for scoring	Post team score and pick up folder		Turn in folder containing answer sheets and test

Fig. 3. The readiness assurance test activity sequence.

Adapted from Michaelsen, Knight, and Fink.[2]

Scores in three major performance areas will determine grades: *Individual Performance, Team Performance,* and *Team Contribution.*

Grade Weights:	Grade Weights and Percentages Within Area	of Total
1. *Individual performance* (minimum = 50%)		50 %
Individual Readiness Assurance Tests (minimum = 25%)	25 %	
Journal Reflections (minimum = 10%)	25 %	
Final Exam (minimum = 50%)	50 %	
2. *Team performance* (minimum = 10%)		40 %
Team Readiness Assurance Tests (minimum = 30%)	40 %	
Manuscript Critique (minimum = 10%)	20 %	
Laboratory Reports (minimum = 30%)	30 %	
Research Presentation (minimum = 10%)	10 %	
3. *Team contribution* as evaluated by peers (minimum = 10%)		10 %

Fig. 4. Grading criteria in the KINES 515 Exercise Physiology Laboratory. Instructor-determined minimums are in parentheses, whereas class-selected weights are underlined.

2) within the individual performance area, at least 50% of the grade must be based on the final exam (Fig. 4).

The team contribution was determined twice during the semester. Each individual evaluated the contribution of the other team members at the midterm and during the final exam by assigning an average of 10 points to the other team members. For example, members of a 6-member team *1*) must assign a total of 50 points to the other 5 members of their team (for a 5-member team, this it would be 40 points; for a 7-member team, this would be 60 points; etc.) and must differentiate some in their ratings and *2*) must give at least 1 score of 11 or higher (with a maximum of 15) and at least 1 score of 9 or lower. Team contribution scores were the average of the points received and produced grade differences only within teams. Team members could not help everyone in their team get an A by giving everyone high peer evaluation scores.

TBL has been extensively used in lecture courses; however, there is little evidence of its use in laboratory courses. The purpose of this report is to describe the implementation of TBL in a graduate exercise physiology laboratory. This was done with the goals of *1*) placing the responsibility for learning on the student and increasing student accountability; *2*) increasing student-centered teaching; *3*) increasing content learning, skill development, and retention; *4*) increasing the time spent on task, i.e., working with the equipment and analyzing results; and *5*) enhancing student critical thinking and problem solving. In this report, TBL will first be described followed by how it was implemented in a graduate laboratory course and then by a discussion of this implementation.

TBL in the KINES 515 Exercise Physiology Laboratory

The KINES 515 Exercise Physiology Laboratory is a three-credit graduate laboratory course that accompanies the graduate exercise physiology course. It meets once a week for 3 h.

- Collaborate with others to examine and assess human physical performance.
- Demonstrate the ability to accurately and reliably measure the various components of human physiological performance.
- Apply the theories and techniques of exercise physiology to answer questions regarding human performance.
- Design research studies that will address a stated problem and test relevant hypotheses.
- Demonstrate the ability to think critically and solve problems.
- Reflect on and self-assess learning, understanding, and ability.
- Apply the theories and techniques of exercise physiology to determine current fitness levels and identify personal lifestyle factors that impact fitness, health, longevity, and quality of life.

Fig. 5. Course objectives in the KINES 515 Exercise Physiology Laboratory. At the completion of this course, the student will be able to complete the course objectives shown.

	Topic	*Question of the Week*
1.	Strength	How well does the strength of a single joint open kinetic chain isokinetic or isometric movement predict maximal strength performance of an open kinetic chain isotonic multijoint movement? Does this vary for upper vs. lower body movements?
2.	Anaerobic Power	Which testing method provides the greatest peak power? How does this peak power compare to maximal strength?
3.	Cardiovascular	What is the relationship between myocardial oxygen consumption during maximal steady state aerobic exercise and differences in heart variability before and after said exercise?
4.	Pulmonary	What is the relationship between resting maximal voluntary ventilation, exercise myocardial oxygen consumption and exercise carbon dioxide production? During normal moderate steady state aerobic exercise With a simulated interstitial lung disease during moderate steady state aerobic exercise With simulated emphysema during moderate steady state aerobic exercise Based on your results, how would ventilatory control be altered by these disease states?
5.	Aerobic Power	What is the relationship between maximal oxygen consumption, ventilatory threshold, heart rate, energy substrate utilization, and the amount of muscle mass used during exercise testing?
6.	Body Composition	What is the effect of moderate dehydration and subsequent rehydration on various methods of assessing body composition?

Fig. 6. Topics and questions in the KINES 515 Exercise Physiology Laboratory.

The university catalog states that it is a "Practical application of the principles that govern response and adaptation of the human body to exercise, utilizing laboratory equipment to collect data and analyze results." The intent is geared more toward teaching laboratory techniques, data collection, and data management than content. However, some content knowledge is necessary to understand the use of the equipment and

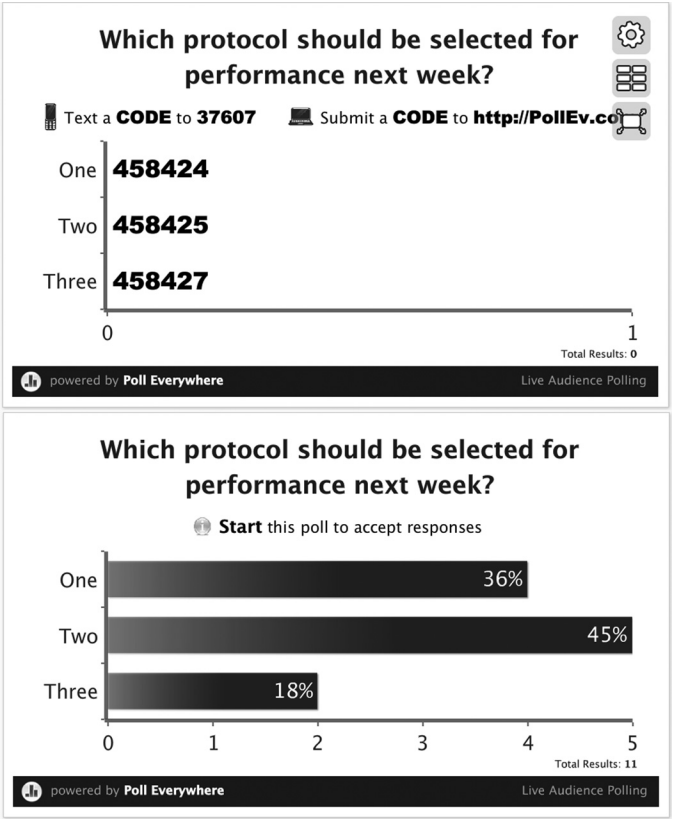


Fig. 7. The Poll Everywhere online system (http://www.polleverywhere.com/) used for student determination of the protocol to be used in the KINES 515 Exercise Physiology Laboratory.

the interpretation of results. An exercise physiology course is a prerequisite for this laboratory course. Intended course learning outcomes are shown in Fig. 5.

Teams were formed based on how students ranked their comfort/familiarity with the equipment found in the exercise physiology laboratory and their knowledge of the concepts of exercise physiology. Student teams were arranged so that there was a continuum of rankings from high to low on each team to increase the diversity of content knowledge and skill.

There were six RAPs during the course, one at the beginning of each major topic (Fig. 6). Once all student questions on the content were answered after each RAP, a case study requiring application of the content was presented as the Question of the Week (QoW). Teams were asked the same question (4S *no. 2*), which could be answered based on the background reading in each area and using various testing protocols and a variety of exercise physiology laboratory equipment. Topics and particular questions were selected with the intention of making them significant to the students and their future goals (4S *no. 1*). For example, several of the students enrolled in the KINES 515 course have a clinical focus; thus, the pulmonary function testing activity was centered on pathological alterations in pulmonary function.

The QoW was briefly discussed as a class to ensure understanding of the question, and teams were then provided in-class time to design protocols that they believed would answer the QoW (4S *no. 3*). The protocols were compiled in a standard format and anonymously submitted to the course website for discussion. Protocols were discussed, and the best option was selected via individual voting at Poll Everywhere (http://www.polleverywhere.com/; Fig. 7), a website that allows students to use their cell phones or web devices to submit a vote. One member from each team then rolled a die to determine which team would be randomly assigned to conduct the protocol during the next class meeting. (Teams were removed from the rotation for the next protocol assignment until all teams had a turn to conduct a protocol.)

Equipment setup and exploration required the assigned team to contribute additional time outside of the regularly scheduled class time. Teams met with the instructor to ensure they understood the equipment and how to implement the protocol. Laboratory protocols were then implemented in the next class meeting with the selected team taking the lead. All class members served as technicians and participants. Some data collection did require additional time outside of the regularly scheduled class time due to the length of the protocols and limited equipment (i.e., maximal O_2 consumption testing).

Simultaneous report out. At the conclusion of the data collection, the lead team collected and posted all of the data on a web document that all students could access. In lieu of a traditional "laboratory report," teams met outside of class to generate a research poster presentation that summarized the previous week's protocol, data collection, results, conclusions, and answered the QoW. A PowerPoint template was provided. Posters were submitted to the instructor and posted anonymously and simultaneously (4S *no. 4*) for the teams to review (Fig. 8). Posters were reviewed, discussed, and team graded at

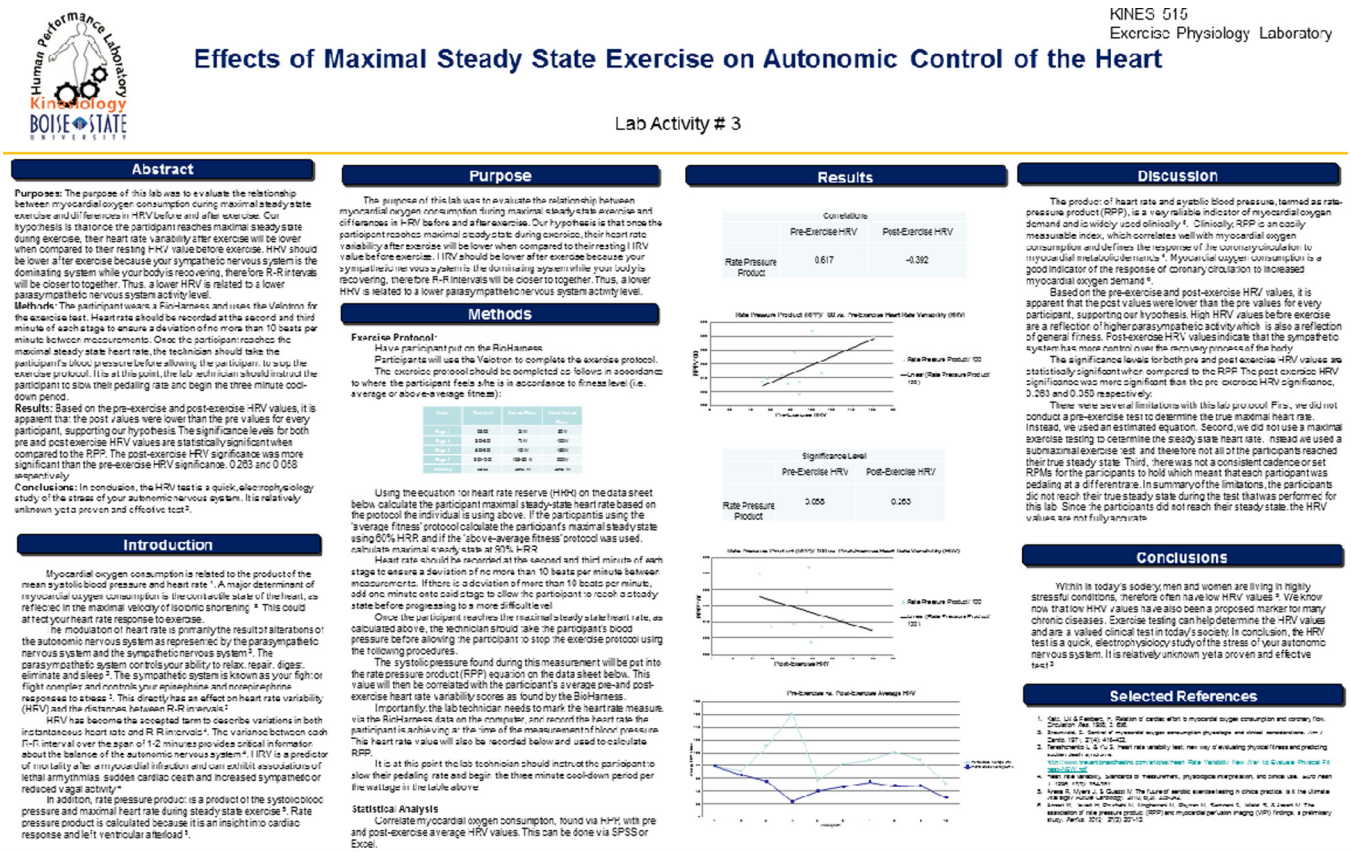


Fig. 8. A sample student poster report in the KINES 515 Exercise Physiology Laboratory.

the beginning of the next class session using the rubric shown in Fig. 9. The instructor also graded the posters using the same rubric. Team and instructor scores were discussed, averaged, and then assigned to the respective teams. The entire process was then repeated (Fig. 10).

Independent of TBL, students were asked to reflect on their laboratory experience after the completion of each laboratory (poster) report. They completed one entry per laboratory report (6 entries/semester). These journal assignments were a personal reflection/assessment and had two components: *1*) assessing personal fitness and *2*) assessing their ability to perform the skills of exercise testing. Journal entries were to use complete sentences and all other aspects of correct grammar and spelling. These were submitted via the course Blackboard site.

At the end of the semester, each team was required to present an oral research presentation. Teams selected one of the QoW questions asked over the course of the semester; objectives were to revise their previous poster and prepare an oral presentation suitable for a national meeting. The oral presentations were made during the last class of the semester and were graded using a provided rubric.

An individual final exam was cumulative, open book, open note, and required applying the concepts learned across the semester. This exam was individually completed via the course Blackboard webpage during finals week.

1	Simonson		KINES 515		
2					
3		Laboratory Report Trait Analysis Rubric			
4					
5		Name:			
6		Lab:			
7		Total:	0	/45	
8	Title				
9	Introduction				
10	Scientific Format Demands				
11	Methods				
12	Experimental Design				
13	Controlling Variables				
14	Collecting Data and Communicating Results				
15	Interpreting Data: Drawing Conclusions/Implications				
16	Literature Cited				

KINES 515
EXERCISE PHYSIOLOGY LABORATORY
LABORATORY REPORT TRAIT ANALYSIS RUBRIC

Title
- 5 – Is appropriate in tone and structure to science journal; contains necessary descriptors, names, and allows readers to anticipate design.
- 4 – Is appropriate in tone and structure to science journal; most descriptors present; identifies function of experimentation, suggests design, but lacks names.
- 3 – Identifies function and name, but does not allow reader to anticipate design.
- 2 – Identifies function or name, but not both; lacks design information or is misleading.
- 1 – Is patterned after another discipline or missing.

Introduction
- 5 – Clearly identifies the purpose of the research; states a hypothesis; identifies interested audience(s); adopts an appropriate tone.
- 4 – Clearly identifies the purpose of the research; identifies interested audience(s).
- 3 – Clearly identifies the purpose of the research.
- 2 – Purpose present in Introduction, but must be identified by reader.
- 1 – Fails to identify the purpose of the research.

Scientific Format Demands
- 5 – All material placed in correct sections; organized logically within each section; runs parallel among different sections.

Fig. 9. The grading rubric used to grade team poster presentations in the KINES 515 Exercise Physiology Laboratory.

Odd Weeks: *Content Discussion and Question of the Week*
- Simultaneous Report Out (PowerPoint Posters)
- RAP
- Protocol Development
- Protocol Selection (PollEverywhere)
- Protocol Assignment (Roll of die)

Even Weeks: *Protocol Implementation*
- Protocol
- Assignment of readings for next week

Fig. 10. Team-based learning class activity rotation in the KINES 515 Exercise Physiology Laboratory. RAP, readiness assurance process.

Student Responses

Students were anonymously surveyed at the end of the course. Most students reported liking the structure of the course and TBL. They particularly enjoyed the protocol development and being able to make the decisions as to what they would actually be doing in the course. The readings were well received, and students liked the combination of text and research manuscripts. The laboratories were perceived as the most important and valuable part of this class. Students stated that they learned how to use the equipment as a technician and received valuable personal feedback as a research participant. Most indicated that their teams worked well together. Students also liked the non-TBL laboratory journals as an individual assignment that helped tie in each laboratory and encouraged them to reflect on their learning and physical conditioning.

Those who did not like TBL generally did not like having to rely on classmates who did not pull their weight. In response to this, students did provide each other feedback on their team contributions and worked to get their teammates more involved. Students also believed that there was a lot of outside work for the class and that the RATs were difficult (Table 1).

Instructor Responses

TBL, like any other pedagogy, has positives and negatives. In this laboratory course, however, the positives outweighed the negatives. Tips for those considering transitioning a laboratory course to the TBL pedagogy include the following:

1. Changing pedagogy is time intensive. Most of the instructor out-of-class work is shifted to planning, preparing, and implementing materials; however, this should carry over to time savings when the course if offered again in the future. There is a time savings in that the amount of instructor-dependent grading is reduced.

2. Good test/RAT questions are crucial (25 items is the maximum), and it is important to commit the time necessary to create good questions. Student appeals can help identify and improve weaker questions. Good, challenging questions get the students talking and thinking critically about the material. While the students felt that there was a lot of outside work for the class and that the RATs were difficult, this seems appropriate for a graduate-level course.

3. Time limits need to be set for tests and activities. Students work faster and stay on task better when they know they are working against a deadline.

4. A greater percentage of the grade was assigned to individual assignments in this application of TBL compared with the author's first forays into this pedagogy. This helps reduce social loafing and increase individual preparation, contribu-

Table 1. *Student evalution of the TBL process*

	Range	Mean
Demographics		
Sex, no. of students		
Women: 5		
Men: 6		
Age, yr		26 ± 5.4
Objectives for the class		4.7
1. I understand the course content.	4–5	4.6
2. I am able to apply the course content.	4–5	4.6
3. I have developed interpersonal and group interaction skills.	5	5
4. I have developed skills for lifelong learning.	3–5	4.5
5. I enjoyed the course.	4–5	4.6
6. Please share any additional comments regarding the outcomes of your involvement with this class.		
All of the activities in class helped me gain more knowledge on the content, which will apply to my future career as a health practitioner.		
I couldn't apply all of the content, more specifically, the relationships between some of the tests.		
I enjoyed having a group teach the labs and for all of us to be both participant and researcher.		
I learned how to perform multiple lab tests proficiently.		
I love the hands-on application of concepts.		
I though coming up with our own protocols instead of simply redoing previous studies was very beneficial.		
[TBL] helped me gain knowledge of the content.		
The hands-on experience enhanced my learning.		
Impact of TBL on learning		3.8
1. The TBL approach was an appropriate way to structure this course.	2–5	3.9
2. The TBL approach enhanced my learning experience in this class.	2–5	3.7
3. I recommend using the TBL approach in future courses.	2–5	3.9
4. Please share additional comments about the TBL process, as experienced in this class.		
It was great working together to design the protocol.		
Sometimes TBL inhibited my learning. We had to rely on other students for testing measures to be correct.		
TBL is a great way to learn and teach each other.		
We might have learned more had we done things more individually.		
With the development of protocols, TBL works well.		
Value of peer assessment		3.4
1. The peer evaluation system encouraged effective team member involvement.	1–5	3.6
2. The peer evaluation system for this course enhanced my learning experience in this course.	1–5	3.2
3. I recommend using the peer evaluation system in this course for future courses.	1–5	3.5
4. Please share additional comments about the peer evaluation process, as experienced in this class.		
Effective for encouraging participation.		
Peer evaluation does not seem to change behavior.		
Personal bias can affect grading.		
Additional comments		
I am not huge fan of the percentage of your grade which is dependent upon other group members' work.		
I love the iRAT and tRAT process.		
I really enjoyed the class overall.		
The RATs were way hard.		
This was a fun course.		

TBL, team-based learning; RAT, readiness assurance test; iRAT, individual RAT; tRAT, team RAT.

tions, and accountability. Increasing the value of the peer evaluation may also limit social loafing in that, if the effect of the peer evaluation is large enough, it is in the student's interest to contribute to the team. The combination of a high individual contribution and peer evaluation weighting may be the most effective strategy.

5. Students really like the application/case study/QoW. They anecdotally reported that they learned the material better, improved recall, and "thought outside the box" more. At the same time, well-designed case studies (QoWs) are critical. The 4Ss need to be followed.

6. Interactions between students and with the instructor are improved (less formal, more relaxed, and more meaningful). Questions are more specific, contemplative, and creative. This helps students see how an expert thinks about the content and applies the concepts. In addition, the instructor can help the students see how the content is meaningful and applies to their personal goals. The instructor also gets to know the students better and can provide better career advice and serve as a stronger reference for future job/education applications.

Conclusions

Using TBL in a graduate laboratory course was very successful and well received by both the students and instructor. Students took on the responsibility for learning and were more accountable. Rather than being dictated to, the learners controlled the process and their own education; the instructor

facilitated their development. Students reported increased content learning, skill development, and retention. Virtually all of the course time was on task. And while no objective measures were made, learners reported, and the instructor observed, enhanced critical thinking and problem solving.

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DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

AUTHOR CONTRIBUTIONS

Author contributions: S.R.S. conception and design of research; S.R.S. performed experiments; S.R.S. analyzed data; S.R.S. interpreted results of experiments; S.R.S. prepared figures; S.R.S. drafted manuscript; S.R.S. edited and revised manuscript; S.R.S. approved final version of manuscript.

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