Team-Based Learning in an Engineering course: an experience in Brazil

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Abstract

Team-Based Learning (TBL) is an active learning strategy, used for the first time in medical education, and its use in Engineering Education is still not well established as in health science education. This work is about an experience of use of TBL in two consecutive years (2017 and 2018) in undergraduate Engineering course in a public university in Brazil. The objectives are to describe an experience using TBL, its impact over students' performance and perception of students and teacher about this approach. Initially, students were divided into groups from 5 to 7 members. The subject of the courses was divided into 4 modules, each one of 4 weeks. Each module started with the Readiness Assurance Process - RAP (pre-class individual assignment, e.g. readings), followed by in-class Individual Readiness Assurance Test – *iRAT*, and Team Readiness Assurance Test – *tRAT*. Both tests were applied using Information Technology tools, in this case either Socrative, or Kahoot or Plickers. During classes, students performed activities designed to develop students' critical thinking skills, applying concepts learned from RAP. Moreover, the students had to perform processes of self and peer-assessment. Average scores from the RAP were statistically higher in tRAT (group tests) than in iRAT (individual tests) (t-test; $p \leq 0.05$), in both years, indicating that teamwork and peer-instruction were important to achieve a greater understanding of the subject. The perception of the students about TBL was collected by an end of class questionnaire. For 81% of the students, TBL methodology was better than teacher centred classes. Another point to be highlighted was the use of Information Technology tools for feedback, approved by 100% of the students who answered the inquiry. As suggestions for future improvements emerged the need to improve the didactic material for pre-class studies.

Keywords: Tem-Based Learning; Peer Instruction; Peer Evaluation; Teamwork; Feedback.

1 Introduction

In the last decades Engineering Education has become an increasingly field of interest (Lima, De Graaff, Mesquita, & Aquere, 2018). Project-based and problem-based learning are widely used and well-known pedagogies in this field (Henri, Johnson, & Nepal, 2017). However, reports on Team-Based Learning (TBL) implementation in engineering and science education are scarce (Najdanovic-Visak, 2017).

Team-based learning (TBL) is an active learning approach based on small group instructional strategy that provides students with opportunities to apply conceptual knowledge through a sequence of activities that includes individual work, teamwork and immediate feedback (Parmelee, Michaelsen, Cook, & Hudes, 2012). TBL was originally developed for a business administration school to promote the benefits of small-group teaching in a large group setting, as an alternative for classes taught by the lecture method (Michaelsen, Watson, Cragin, & Dee Fink, 1982).

The primary learning objective in TBL is to go beyond simply covering content and focus on ensuring that students have the opportunity to solve problems using course concepts. Thus, TBL is designed to provide students with both conceptual and procedural knowledge. Team-based learning (TBL) has many aspects (Michaelsen & Sweet, 2008):

- ✓ group work is central to exposing students to and improving their ability to apply course content;
- ✓ the vast majority of class time is used for group work;
- ✓ courses taught with TBL typically involve multiple group assignments that are designed to improve learning and promote the development of self-managed learning teams.

TBL is a pedagogical approach that can be implemented through the following four elements (Michaelsen & Sweet, 2008):

(i) Groups: must be properly formed and managed.

(ii) Accountability: Students must be accountable for the quality of their individual and group work.

(iii) Feedback: Students must receive frequent and immediate feedback from the teacher.

(iv) Assignment design: group assignments must promote both learning and team development.

TBL's strategic sequence, when repeated multiple times during a course or academic term, encourages conscientious individual preparation while developing teams into cohesive learning groups. Faculty motivate students to thoroughly study the advance assignment by writing questions that assess mastery of critical concepts in that assignment. TBL provides frequent opportunities for peers to enhance learning, as teammates talk and listen to one another to arrive at consensual reflected decisions. Faculty invite teams to explain and support their choices publicly, and facilitate as teams debate justification for the best decision. Ideally, application questions require students to engage in critical thinking, rather than to merely retrieve relevant knowledge. Well-crafted application questions motivate teams to "make a concrete decision based on analysis of a complex issue." Faculty often observe considerable energy and engagement of students during intra and inter team discussions (Koles, Stolfi, Borges, Nelson, & Parmelee, 2010).

The aim of this work is to discuss the experience, evaluation and lessons learned from the implementation of the TBL within two Environmental Engineering courses in the years of 2017 and 2018.

2 Description of the TBL implementations

This study is an experience of implementing TBL as a methodology for teaching in two Environmental Engineering courses in an undergraduate program at a public university in Brazil. This experience was done in a first year (Ecology course, year 2018, 39 students) and third year (Limnology course, years 2017 and 2018, 40 and 27 students, respectively) courses. TBL strategy was implemented based upon Michaelsen & Sweet, 2008, with some adaptations, and will be described in this section.

2.1 Context and process of application

Both courses had an amount of 32 hours each, divided into 16 weeks. Each course was divided into four modules, each module of 4 weeks. Figure 1 presents a workflow of each module. Team formation was done randomly, with the aid of the institutional learning environment, with teams from 5 to 7 members, depending on class size. A total of 106 students have been enrolled on these courses.

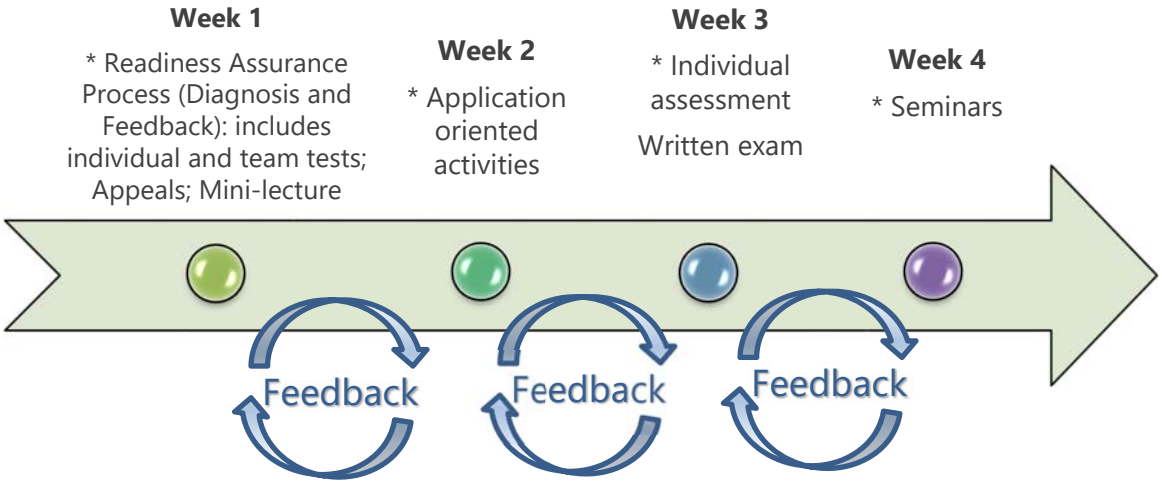

Figure 1. Workflow of each module.

The procedure of each week is described below.

- ✓ *Week 1*: Readiness Assurance Process, with five steps, that are *Pre-class preparation*; *Individual Readiness Assurance Test* (*iRAT*); *Team Readiness Assurance Test* (*tRAT*), both done using Socrative® or Plickers®. On each module the tests had ten multiple choice questions, with four possible answers each. The students had 15±2 minutes for *iRAT* and 20±2 minutes for *tRAT*. The *iRAT* and *tRAT* ensure that students comprehend basic concepts, allowing teacher to move towards more detailed and multifaceted discussions, application activities, and/or lectures (Andersen, Strumpel, Fensom, & Andrews, 2011). *Appeals*: After tests students had the opportunity to make a written appeal, in group, if they do not agree with any question. *Mini-lecture (with discussions)*: after *iRAT* and *tRAT*, based on reports of Socrative® or Plickers®, started this part of the class. Contents covered on topics where there was more doubts, based on reports, were further discussed. Videos, slides, board were also used in order to clarify and give a deeper view on the main topics in this part of the class. Formative assessment was also used, mainly using Kahoot®, which provided competition between individuals or groups.
- ✓ *Week 2: Application oriented activities*, in class. Based on the 4S problem-solving of TBL principles (Michaelsen & Sweet, 2008). These activities were based mainly on case studies, from several sources, cited on each activity. In some occasions an adaptation was done, using the approach "Pass the problem" (Ballard, 2001), with open ended questions. Questions from previous "Brazilian National Exam of Students Performance" (ENADE) were also used successfully. Formative assessment was also used, mainly using Kahoot®, which provided competition between individuals or groups.
- ✓ *Week 3:* Individual test about the subject of the module (written; sometimes, part of it online with instantaneous feedback, using Socrative®)
- ✓ *Week 4*: Seminars with subjects about the actual or previous modules (in teams).

2.2 Assessment process

Any group-based instructional format requires students to be accountable for their learning (Cestone, Levine, & Lane, 2008). In this TBL experiences, each module had a total score of 100% (see Table 1) and the final grade was an average of the four modules. Considering all assessment activities, 60% of the scores were based on individual activities and 40% on group activities.

Table 1. Description of assessments in each module, including individual and group assessment.

Assignment	Weight	Individual Activities	Group Activities
iRAT	10%	X	
tRAT	10%		X
Application activities	5%		X
Self-assessment	5%		X
Peer-assessment	5%		X
Seminars	15%		X
Exam	50%	X	
Total	100%	60%	40%

Self-assessment and peer-assessment, in this case, were related only to activities done in Readiness Assurance Process and Application activities, based on the five criteria described below, using Google Forms®.

1. You/your peer has positively contributed with group discussions.
2. You/your peer has helped the group to be focused on the questions given by teacher.
3. You/your peer has actively contributed with knowledge and opinions.
4. You/your peer worked in harmony with the group.
5. You/your peer previously studied the pre-class material (material given by teacher).

For each question, a 1 to 5 points scale was used, adapted from (LIKERT, ROSLOW, & MURPHY, 1993). Students were instructed about the scales, where the following scores should be used: 1-completely disagree; 2-disagree; 3-neutral; 4-agree; 5-totally agree. The scores for each student were averaged, either for self-assessment or peer-assessment, in a scale of 1 to 5. For grading it was normalized using a weight of 5% for each module.

Individual tests were done at the end of each Module, with open-ended questions and/or multiple choice questions.

Seminars were also done at each module, in group. The subject could be either the same for all groups or one topic for each group, with a brief discussion after the presentation. These seminars were complimentary to the topics covered on each or more than one module, for example, about peer reviewed papers. In seminars, there were also a new criteria for assessment (Michaelsen, Knight, & Fink, 2004): each student was peer-assessed and the average grade provided by group made up a factor. Therefore, the grade of each student on the topic *Seminar* was defined by the grade from teacher multiplied by the factor defined by the group for each student. All the team members had to assess the contributions that each member of the group made to the seminars, taking into account the level of preparation, contribution, flexibility and respect for others. Each student distributed 100 points among other team members. All the members of the team got the "peer evaluation factor", which is the sum of the points they were granted from each teammate, divided by 100. This approach tried to overcome one common complaint by students in group work, that is "an unfair grade" (Fink, 2002), because not all members contributed the same way to the success (or not) of the group.

So, the grade for the Seminars were calculated as Equation 1:

$$Seminar\ grade\ (individual) = Team\ grade\ x\ (peer\ evaluation\ factor) \quad \text{(Equation 1)}$$

2.3 Students' perceptions

A questionnaire comprising six multiple choice questions and one open-ended question were done by students, at the end of the term, using Google Forms®. The questions and its possible answers are presented in Table 2. As it was not mandatory, only 42 students from an amount of 106 completed this form. In each question students had to choose one possible answer.

2.4 Students' scores

In *iRAT* and *tRAT* students did the same test twice, first individually and afterwards on teams. So, *t-test* for paired samples was used to test if averages differed statistically, at a confidence level of 95%, using Microsoft Excel® "Data Analysis" tool. In this case, for all the courses the scores of the four modules were compared. If a student eventually missed the class his data was excluded from analysis, for both *iRAT* and *tRAT*.

Students also graded themselves (self-assessment) and their teammates (peer-assessment). *t test* was also used to check if average scores differed, at a confidence level of 95%, using Microsoft Excel® "Data Analysis" tool. Grading was done using Google Forms®. Sometimes some students failed to do the self-assessment (so, his grade on this item was considered zero) and the data were excluded from analysis, together with the respective peer-assessment.

Table 2. Questionnaire to students' perception about TBL.

	Questions	Possible answers
1.	**Group formation, by instructor, was?**	( ) Very good, I was closer to colleagues who I had little contact.
		( ) Bad, I already have my preferred group and doing this way it did not work as it usually did.
		( ) I liked, in the job market I would hardly have the chance to choose my co-workers
		( ) For me it was indifferent, I get along well with everyone.
		( ) I do not know or I do not want to answer
2.	**Activities done in teams, as solving questions in class, seminars, were they important to improve the learning goals of the course?**	( ) Yes
		( ) Reasonably
		( ) Not
		( ) I do not know or I do not want to answer
3.	**Dividing the contents of the course into 4 modules, with previous study in each module requested, for me it was...**	( ) Very good, because it allowed to me to use the time in class to clarify my doubts, as I always studied the material before classes.
		( ) The same as lectures, because I could not understand completely the material content.
		( ) Bad, because it already had many other activities of other disciplines and therefore I had no time to study the material previously.
		( ) I prefer lectures, with teacher centred classes.
		( ) I do not know or I do not want to answer
4.	**The material available for previous studies, at the beginning of each module, was generally ...**	( ) Insufficient
		( ) In accordance with the content
		( ) Extensive
		( ) Confuse
		( ) I do not know or I do not want to answer
5.	**About learning check methods using online Information Technology tools and instantaneous feedback.**	( ) I did not like, as I prefer exams using paper, in a traditional way
		( ) I liked, it is better because you have instantaneous feedback and it is better than using paper.
		( ) For me it does not matter
		( ) I do not know or I do not want to answer
6.	**About the use of TBL strategy during the course, you consider that it was...**	( ) Better than lectures
		( ) As same as lectures
		( ) Worse than lectures
		( ) I do not know or I do not want to answer
7.	**Open ended question**	If wanted, leave a compliment, criticism or suggestion about the discipline. Feel free to write, be honest so that the discipline can be improved the next time it is offered. If you want, identify yourself.

3 Results and discussion

Discussion will be based on three aspects: students' perspectives; teacher's perspectives; student's scores.

3.1 Students' perspectives

Fifty percent of the respondent students said that liked group formation by the teacher. An argument is that in labour market probably they will not have the opportunity to choose whom they were going to work with. For 38% of students it was indifferent, as they got along well with everyone.

About the group activities, 56% agreed it improved learning, while 31% considered it was not so good and 13% considered that group activities did not improve learning.

About the courses and their division into 4 modules, 56% of students answered that it was not a good idea. But the reason they said that is because they had other courses and because of that they did not have enough time to do the due activities. For 25% of students, TBL was considered very well, because it allowed these

students to use class time to ask questions and clarify some topics about the content. 6% did not like TBL, other 6% consider TBL as same as lectures and 6% do not know or did not want to answer.

With respect to the previous material, they complained about it, as 88% said that the material was too extensive or too complicated. Students also complained about the time to dedicate to previous study, because they had also five or even more courses simultaneously, so they said they did not have sufficient time to dedicate to study the material. This is a point that clearly should be improved. Giving the students an extensive material (it was mainly book chapters) has not given students a good opportunity to learn, because they do not have time to read it carefully. Remington, Hershock, Klein, Niemer, & Bleske, 2015 also observed that this was a problem when trying to implement TBL in a pharmacy course, observing that the texts were not ideal for time-limited self-instruction and caused excessive workload to students.

A challenge here could be to create new types of materials that are complete, in terms of content, but that are easier to understand and to deal with the main ideas of the subject, for the previous study. So, later in class will be possible to work deeper into content with book chapters and other materials with more information

The only aspect students were unanimous is about the use of Information Technology (IT) tools (Socrative®, Plickers® and Kahoot®) for formative or summative assessment. They really liked the use of them. Aspects like ease of use, instantaneous score feedback, competition with pairs (in this case, mainly Kahoot®) were aspects that increased their engagement and approval of these tools.

A large majority of the students (81%) considered TBL better than lectures, 13% considered TBL worse and 6% did not know.

Another complaint that emerged on the open-ended questions was also about grading all classes. Some students felt this was not good because sometimes they were not able to be present in class and felt impaired.

3.2 Teacher's perspectives

It was clear that during the classes students were more engaged in discussing the questions, although they do not always realized that. A better level of participation and peer instruction could be perceived. Students improved their learning, by discussing with their peers. For Webb, 1995, group work promotes learning encouraging discussions and debate, which leads to the justification of ideas, resolution of disagreements and understanding of new perspectives.

The use of Socrative®, Plickers® and Kahoot® also improved the quality of the teaching and learning process. In the teacher's perspective, with the instantaneous feedback and a sheet of answers provided by these IT tools, it was possible to focus the mini-lecture on the most important topics that students had trouble, based on the tests results. This approach was very efficient, but it has some limitations on the wireless internet provided by the institution, that sometimes was unstable. Despite this, it has proved a very good way to give feedback, as it was not necessary to use paper forms and correct them manually. Socrative® was a very important tool to improve feedback about formative and summative assessment. As also described by Dervan, 2014, Socrative® permitted that the main questions about content could be discussed and cleared in class, also improving students' interaction.

The preparation of previous material and in-class activities (Readiness Assurance Process and application activities) was very time consuming, as also reported by (Andersen et al., 2011; Remington et al., 2015). Nevertheless, it clearly increased the level of discussions and students' engagement during classes. Also Koles et al., 2010 observed that both faculty and students noted that TBL's emphasis on individual preparation and peer-to-peer teaching seemed to enhance learning.

The previous material is one point that clearly emerged from students perspectives that should be improved. The material was cited to be confused or too extensive, so it could have obscured students' performance. For future applications of TBL, this should be a point to be improved, namely giving students a more resumed material. The use of videos and other more interactive tools is a perspective to be reached in the future. To reach that Vatterot, 2010 describes five fundamentals that homework should have: purpose, efficiency, ownership, competence and aesthetic appeal.

Other possible approach is integrate TBL with Problem and/or Project-Based Learning (PBL). As the courses have theoretical and a practical components, the use of TBL for theory and PBL for practice could improve even more students' learning and outcomes.

3.3 Students' scores

The average scores and standard deviation for exams were 70%±18% for Limnology 2017; 75%±15% in Limnology 2018 and 72%±18% in Ecology 2018. These averages are consistent with the histogram of Figure 2, where the interval 71-90% was the most common score of the students on the courses.

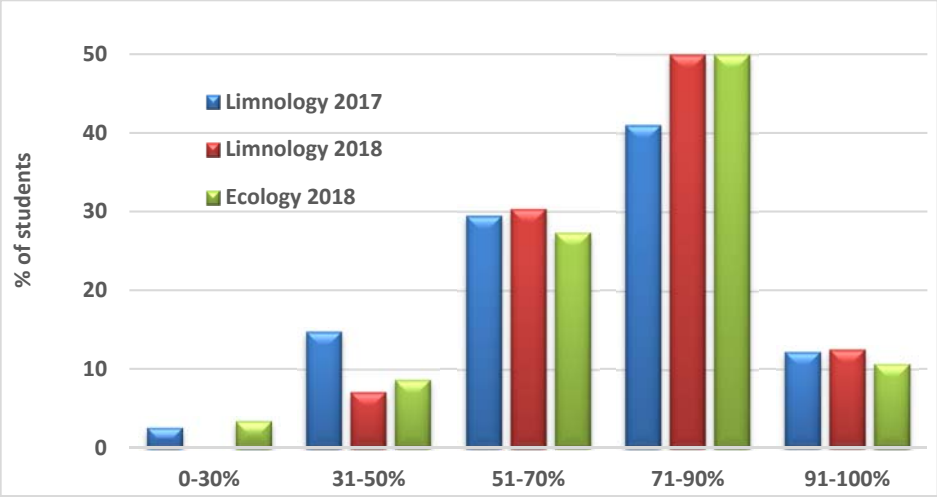

Figure 2. Exams scores in courses. Abscissas refers to scores intervals.

Scores were compared individually and in teams, in *iRAT* and *tRAT*, respectively, in Table 3. For the two courses it was observed that the average grade in *tRAT* was statistically higher than in *iRAT*, in both years, 2017 and 2018. Results indicates that average team scores outperformed individual scores from 15% to 24%, suggesting team interactions, as also observed by Najdanovic-Visak, 2017. When comparing scores between the two years in Limnology course, scores in *iRAT* did not differ ($p \leq 0.05$), but *tRAT* were statistically higher in 2017 than in 2018 ($p \leq 0.05$). Considering self-assessment and peer-assessment (except those in seminars), average scores did not differ statistically for all courses, either in 2017 or 2018 ($p \leq 0.05$).

Table 3. Statistical analysis of *iRAT* and *tRAT*.

	Limnology course		**Ecology Course**
	2017	*2018*	*2018*
***iRAT* average**	67.7%$^{a,\alpha}$	61.3%$^{a,\alpha}$	68.2%^{a}
***tRAT* average**	92.3%$^{b,\beta}$	81.3%$^{b,\Omega}$	83.4%^{b}
p-value	<0.001	<0.001	<0.001

^{a,b}: averages differ statistically, $p \leq 0.05$, same year. Greek letters: averages comparing 2017 and 2018; same letters: no difference ($p \leq 0.05$).

4 Conclusions and recommendations

TBL proved to be a good strategy to improve students' engagement in the learning process. The use of Information Technology tools seemed to be very effective in helping teacher to give instantaneous feedback that could lead teacher's interventions to the most important topics, according to results of the tests. Students seemed to be more engaged, as the quality of class activities increased. About students' perception, 81% considered TBL better than lectures and that it improved learning. 56% of the students also considered that group activities improved learning. The use of Information Technology tools for feedback was approved by 100% of the students who answered the inquiry. Peer instruction seemed to be an important outcome of TBL,

increasing scores and learning, as suggested by statistical analysis that demonstrated higher scores up to 24% higher in group activities than in individual activities. The main recommendations that emerged from the results are the improvement of material for previous study, turning them more suitable with the time students have to do it, as they have several other simultaneous courses. Furthermore, future integration of TBL with Problem and/or Project-Based Learning (PBL), in theory and practice into these courses could improve even more students' learning and outcomes.

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