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EDITED BY
Víctor Arufe Giráldez,
University of A Coruña, Spain

REVIEWED BY
Jamie Jensen,
Brigham Young University, United States
Marco G. Alves,
Independent Researcher, Porto, Portugal

*CORRESPONDENCE
Margarida Fardilha
✉ mfardilha@ua.pt

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Engaging large classes of higher education students: a combination of spaced learning and team-based learning

Vânia Carlos[1], Mário Rodrigues[2], Bárbara Matos[3], Lurdes Gonçalves[4], Fernando Ribeiro[4] and Margarida Fardilha[3]*

[1]CIDTFF–Research Centre on Didactics and Technology in the Education, Department of Education and Psychology, University of Aveiro, Aveiro, Portugal, [2]Health Sciences School, University of Aveiro, Aveiro, Portugal, [3]Department of Medical Sciences, Institute of Biomedicine–iBiMED, Campus Universitário de Santiago, Aveiro, Portugal, [4]Health Sciences School, Institute of Biomedicine–iBiMED, University of Aveiro, Aveiro, Portugal

We are in an era where keeping students focused and interested can be challenging. Furthermore, it is relevant, in avoiding students dropping out and increasing students' achievements, to research how student engagement can be nurtured and how this aspect is influenced by teacher attitude and the teaching and learning (T and L) approaches. With the purpose of engaging a large biochemistry class of first-year students (n = 170 in the pilot study and n = 147 in the full project) from the Biomedical Sciences degree at the University of Aveiro in Portugal, a combination of two different learning methodologies was implemented: Team-based Learning (TBL) and Spaced Learning (SL). The main objectives of this pedagogical innovation were to promote collaboration between students, keep students engaged throughout the semester, and keep the teacher satisfied through the participation of students in class and positive feedback. A typical class involved various steps which combined different facets of TBL and SL: a bibliography was provided one week in advance to the students for them to get familiarized with it; in class, the students answered an individual quiz, followed by a group quiz; the next step was solving a problem. Meanwhile, an SL break occurred in which students did distracting activities (usually physical activities). Lastly, a short seminar in the form of a Q & A occurred to clarify any doubts. The assessment of this class involved different individual and group components. Qualitative and quantitative data were collected through focus group interviews, questionnaires, and observation techniques. After analyzing the results, in general, we can conclude that students seem to prefer learning with TBL and SL than with traditional methodologies. Students emphasized the SL as a positive strategy. Furthermore, they acknowledge that teacher attitude was crucial for their engagement.

KEYWORDS

active learning, pedagogical motivation, student engagement, spaced learning, team-based learning, teacher attitude

1. Introduction

The level of student engagement is a crucial factor in facilitating effective learning. Research has consistently demonstrated a positive correlation between engagement and academic success (Fredricks et al., 2004). Conversely, student disengagement has been associated with the likelihood of dropping out of school (Archambault et al., 2009). Student engagement can be enhanced by various factors, such as fostering a positive connection between students and teachers (Klem and Connell, 2004; Roorda et al., 2011) and creating safe learning environments that encourage autonomy (Fredricks et al., 2004).

This study focused on the student. We are interested in understanding how the implementation of a pedagogical innovation that included the combination of Team-based Learning (TBL) and Spaced Learning (SL) in a large class of first-year students related to their engagement.

The article includes a theoretical framework of the teaching and learning (T and L) strategies incorporated into the pedagogical innovation. After, an exhaustive description of the model is presented including the context, the class structure, and the assessment details. The methodology used in the implementation is presented followed by the results of the study and their discussion.

2. Theoretical framework

2.1. Active learning and student engagement

Lectures have been the traditional T and L methodology across all disciplines in higher education (HE) (Brockliss, 1996). For centuries, the teacher-centered approach, in which students were passively receiving content, was never questioned (Skinner, 1976). T and L theories that make the student responsible for their learning, putting the student at the center of their own learning, have emerged. The initial fears associated with its inefficacy have been overcome by evidence-based research coming from different areas of knowledge (Freeman et al., 2014; Serin, 2018). These T and L theories are called active learning strategies and assume that students are highly engaged in their own learning. This factor is key to the success of active learning approaches.

The concept of academic student engagement refers to the active participation of students and their responsibility for their own learning. Examples of students being engaged include the effort that students invest in their learning process, the time spent in studying, the level of interest in the courses they are attending, and the implementation of good study habits (Markwell, 2007; Steele and Fullagar, 2009; Almarghani and Mijatovic, 2017) identified diverse factors to encourage students' engagement, such as (i) the combination of active and interactive learning with co-curricular and extracurricular activities, (ii) the encouragement and support of academic and general staff to implement practices that foster student engagement, and (iii) the promotion of an inclusive environment.

Students perceived a positive change in their engagement consistently over time when experiencing active learning strategies (Kirstein and Kunz, 2015), even when students were in large classes (Hallinger and Lu, 2013).

Despite the inexistence of a universally agreed definition for active learning, there is consensus among the academic community on the general notion of students engaging in activities that push them to reflect on ideas and on how they are applying those ideas, such as talking, listening, writing, reading, and/or reflecting (Bonwell and Eisen, 1991; Hsieh, 2013; Misseyanni et al., 2018). Active learning approaches thus require students to systematically reflect on their level of comprehension and skills, when dealing with problems, challenges, or concepts in a certain course. The process of gathering information, thinking, and problem-solving keeps students engaged in participating and being mentally, and often physically, active in their own learning (Michael, 2006). Another consensual characteristic of the active learning approach is to be student-centered, where students influence the content, activities, materials, and pace of learning (Michael, 2006).

The literature presents a diversity of active learning approaches. Common student-centered active learning techniques are (i) cooperative learning (Dougherty et al., 1995), (ii) collaborative learning (Lumpe and Staver, 1995), (iii) problem-based learning (PBL) (Doig, 1993; Schmidt, 1994; Savin-Baden and Major, 2004; Spronken-Smith and Harland, 2009), (iv) discovery/inquiry-based learning (Wilke and Straits, 2001), (v) challenge-based learning (Roselli and Brophy, 2006), and (vi) concept mapping (Briscoe and LaMaster, 1991). Furthermore, flipped classroom (Saunders and Klemming, 2003; Pombo et al., 2017), TBL (Michaelsen et al., 2014), and peer instruction (Crouch and Mazur, 2001), among others, are also considered active learning approaches. According to Felder and Brent "Active learning is anything course-related that all students in a class session are called upon to do other than simply watching, listening and taking notes" (Felder et al., 2009).

There are many good examples of evidence-based research demonstrating the benefits for all the players involved in using active instead of traditional learning methodologies in pedagogical practices (Michael, 2006). Indeed, it has become clear that class attendance and engagement are higher, and students learn more. Recently, Freeman and colleagues meta-analyzed 225 studies and concluded, by comparing tests grades from undergraduate students under traditional versus active learning, that the average tests grades improved by approximately 6% in active learning, and students under traditional learning were 1.5 times more likely to fail than students under active learning (Freeman et al., 2014).

However, the perception of learning in active learning classrooms is lower than that in passive environments. This fact was shown by comparing self-reported perceptions of learning with real learning. The authors suggested that initial cognitive effort applied in active learning may be detrimental to the learning motivation of students. This is usually overcome with time, when students realize the benefits of their own engagement in the learning process (Barr and Tagg, 1995; Deslauriers et al., 2019).

Still, there are also critical issues when implementing active learning strategies: (1) the learning environment must be built by the professor who needs to be familiar with active T and L approaches, thus, faculty development is key; (2) the ratio professor/student is usually higher in active learning than in traditional teaching, which increases the number of professors that need to be hired; (3) suitable infrastructure is needed (appropriate classrooms for group work, for example); (4) supporting infrastructure for research and teaching, and (5) learning designers (Børte et al., 2020).

The following paragraphs detail the active T and L methodology implemented in the context of this study: a combination of TBL and SL methodologies.

2.2. Team-based learning

TBL is a student-centered and teacher-directed strategy that includes in-class teamwork and assessment, promoting the benefits of small-group teaching in a large-group setting (Parmelee et al., 2012). This methodology has been shown to improve student's grades and classroom engagement (Clark et al., 2008; Chung et al., 2009; Parmelee, 2010). Further, the professors reported increased excitement in their classrooms (Dana, 2007; Nicoll-Senft, 2009; Andersen et al., 2011; Jacobson, 2012).

The perception of students is that TBL is interesting, allows for a deeper understanding of content, and prepares them more efficiently for assessment (Swanson et al., 2019). Indeed, TBL students outperform non-TBL students in examinations (Koles et al., 2005, 2010; Letassy et al., 2008; Zingone et al., 2010; Grady, 2011; Thomas and Bowen, 2011; Persky, 2012; Fatmi et al., 2013). Furthermore, it has been shown from the analysis of 20 years of results that 99.95% of teams outperformed their best member by an average of 14% (Michaelsen, 2002).

In TBL, the formation of groups is key to the success of the method. The professor should create the teams based on students' skills diversity and other relevant characteristics, and the groups should be kept as long as possible (Parmelee et al., 2012). TBL is characterized by three key components: (1) a pre-class content preparation phase; (2) an individual test followed by the same test, performed in groups, after which, the teacher makes a clarification review; and (3) a content application activity, usually a significant problem, which they must interpret and, as a team, organize an answer and be able to explain and defend it (Figure 1A; Kibble et al., 2016; Chhabra et al., 2017; Reimschisel et al., 2017). In general, four principles govern the methodology: (1) groups must be properly formed and monitored; (2) students must be held responsible for their individual and group work; (3) group tasks should promote group learning and development; (4) the professor must give frequent and immediate feedback (Michaelsen et al., 2007).

Unlike in other group work-based methods, in TBL a single professor can facilitate/follow the work of several small groups (5–7 students) within a classroom with many students. It should be noted that TBL was introduced by Michaelsen in the 1970s when he went from a class with 40 to 120 students (Michaelsen et al., 2007). Interestingly, students perceived a larger class size as beneficial to their learning with TBL (Michaelsen, 2002).

2.3. Spaced learning

SL is a T and L methodology that allows information to be quickly captured in long-term memory, based on a particular classroom organization (Figure 1B). It relies on the ubiquitous phenomenon in learning and memory, the spacing effect, first shown by Ebbinghaus (Fields, 2005; Ebbinghaus, 2013). The spacing effect is characterized by the observation that long-term retention is improved if a longer interval exists between study repetitions (Melton, 1970; Kelley and Whatson, 2013; Garzia et al., 2016; Kim et al., 2020).

A common SL class comprises 3 moments (~20 min each) with intense input of information–stimulus–separated by two intervals (10 min–distractors) that must not be related to the content of the class (Kelley and Whatson, 2013). In the first input session, the information that students need to learn is provided and they start to build new memories of the new content they are learning. An interval follows which should not stimulate the same memory neural pathways, thus different activities must be done (preferably manual or physical activities). The second information input session serves the purpose of recalling and revising the key contents of the first, allowing for memory arousing. This may include presenting the content using alternative strategies, for example, short videos or filling blank spaces (in the slides presented in the first session). This session is followed by a second interval that respects the same principles. In the third input moment, student-centered activities are used, so that they can demonstrate the acquisition and comprehension of the contents from the first two sessions (Garzia et al., 2016).

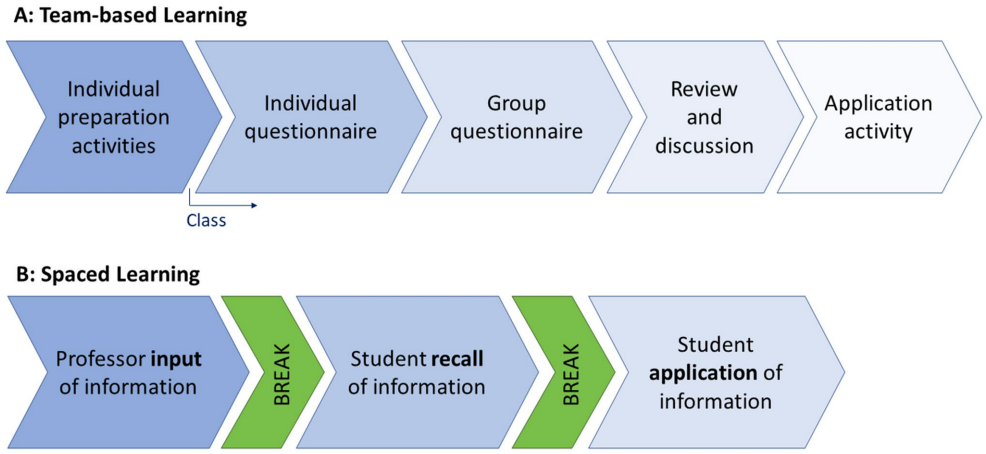

FIGURE 1
Schematic representation of the different T and L methodologies. **(A)** Team-based learning; **(B)** Spaced learning.

A recent review of SL applied to the education of health professionals (Versteeg et al., 2020) concluded that there is a void in the definition of SL in the health profession education literature. The authors identified the need to invest time and resources in helping learners from the health profession retain the information being learned (D'Eon, 2006) through SL approaches.

Furthermore, the application of SL in combination with other methodologies, for example, Inquiry-based learning, has been suggested (Kelley and Whatson, 2013).

3. Proposed innovative pedagogical model–a combination of TBL and SL

3.1. Context

The academic year 2019/2020 was the first year of a profound curricular transition in the Biomedical Sciences Degree in the Department of Medical Sciences at the University of Aveiro. It is important to take into consideration that the students were already familiarized with active learning methodologies, e.g., PBL, in one course per semester. Thus, they were open-minded regarding innovative teaching and learning strategies. This fact facilitates the implementation of new and different teaching and learning experiments.

Seizing this opportunity for change, the professor responsible for the course on Integrative Biochemistry decided to follow the trend that was being implemented, not only in medical but also non-medical schools, and move from traditional lectures, a strategy usually developed in theoretical biochemistry classes, to an active T and L strategy, combining TBL (Kibble et al., 2016; Chhabra et al., 2017) and SL (Kelley and Whatson, 2013; Garzia et al., 2016; Figure 2). The implementation of this T and L strategy was also driven by the growing amount of information available online, which leaves more room for knowledge application activities.

An interdisciplinary group of colleagues (professors, researchers, and non-teaching staff) from the university was involved in this project to help change the conventional way of thinking, both for students and professors. Thus, the main goal of the innovative T and L approach was to promote student engagement while learning occurred in a three-hour class with a theoretical matrix by achieving the following specific objectives: (1) to implement active learning strategies: combining SL and TBL; (2) to develop collaborative and interdisciplinary practices among a group of colleagues with different skills and visions toward T and L; (3) to include students as partners in the design of the T and L environment; (4) to collect and analyze evidence regarding pedagogical practices that can regulate T and L during the academic year; (5) to share the results with the academic community and foster knowledge transfer to similar pedagogical contexts.

3.2. Detailed description of the class structure

A typical class includes several well-defined moments (Figure 3) which are detailed in Table 1. The class structure can be used at distance or face-to-face.

3.3. Assessment details

The assessment was discussed with the students and included an individual and a group component. The main assessment elements (Table 2) were written exams, peer evaluation, TBL evaluation, a project, and attendance.

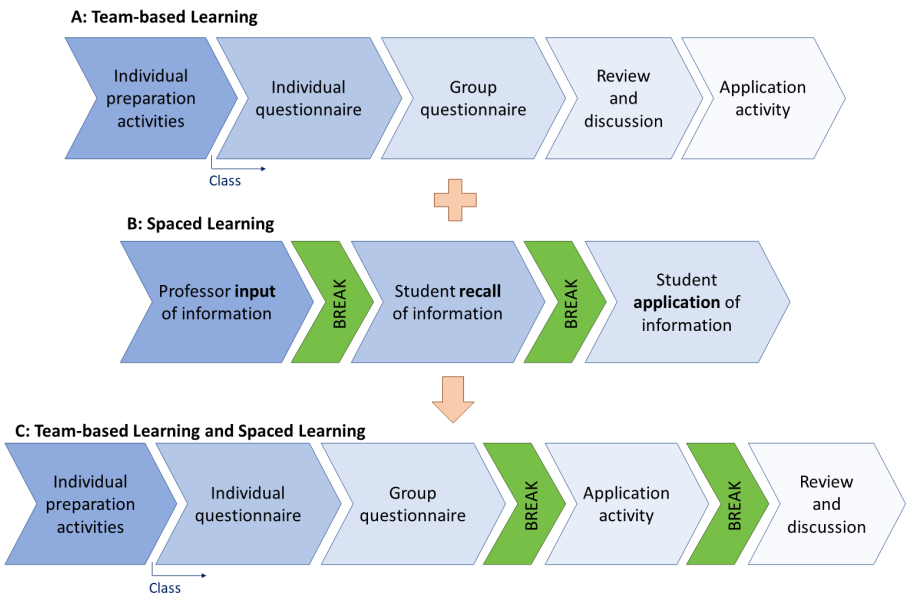

FIGURE 2
Schematic representation of Team-based learning **(A)**, Spaced Learning **(B)**, and the combination of team-based learning and spaced learning, which was introduced in this work **(C)**.

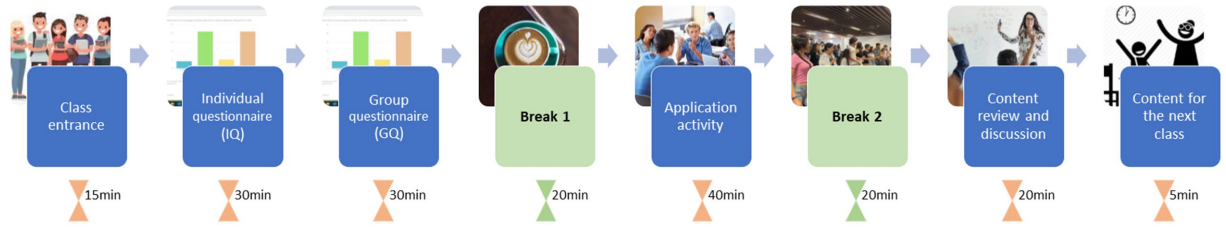

FIGURE 3
Schematic representation of the structure of a class that combines TBL and SL.

The tests (Element A in Table 2) included multiple choice questions, False/True questions where the false should be changed to become true, and questions to analyze clinical cases or apply knowledge in new contexts. In terms of Bloom's level, the tests included remembering, understanding, analyzing, and applying.

Concerning Element E (Table 2), students had in total ~ 10 classes with the TBL methodology (the others were tests). Of those 10, only 3 (for each student) were taken into consideration for their assessment. The other classes were used for formative assessment.

The students developed a project (Element F, Table 2) on metabolic maps in which the output was a poster that was presented at the end of the semester to the class.

4. Implementation and methodology

4.1. Implementation

This study aimed to understand the impact of implementing a pedagogical innovation in a large class of 1st year students which included the combination of TBL and SL strategies and analyzing the impact on students' engagement.

The implementation of this pedagogical innovation occurred in two phases: (1) a Pilot Study and (2) Full Project. The pilot study was conducted in the second semester of the 2019/2020 academic year in the Integrative Biochemistry course. The pilot study was reported by quantitative data (closed questions of a questionnaire; Supplementary Table S2) and qualitative data (open-ended questions of the same questionnaire, Supplementary Table S2). Initially, 14 classes were supposed to be attended by the students. However, the COVID-19 pandemic forced all of us to go to distance learning, and the original planning for the course was altered. Only four classes were based on TBL and SL. Thus, the questionnaire was answered by the students at the end of the semester taking into consideration the experience of the four classes that occurred before the lockdown. The full project was implemented in the second semester of the 2020/2021 academic year in the same course. To monitor the full project implementation, the methodology of design-based research was implemented (Wang and Hannafin, 2005; Amiel and Reeves, 2008). The monitoring data collection was carried out before (before action), during (during action), and after (post-action) the project (Table 3) and included different instruments: a final questionnaire (Supplementary Table S3), a focus group, the professor diary, and teachers observation. Furthermore, some of the Quality Management System (SGQ) indicators from the university were also analyzed, including aspects related to teacher performance and course characterization (Supplementary Table S4).

4.2. Participants

This study focuses on the first-year students of the undergraduate degree of Biomedical Sciences at the University of Aveiro enrolled in the curricular unit of Integrative Biochemistry in the academic year 2019/2020 (n = 170, pilot study) and 2020/2021 (n = 147, full project).

4.3. Satisfaction questionnaires

In both implementation phases, satisfaction questionnaires were used to obtain quantitative data. The final questionnaires included both quantitative and qualitative data (Supplementary Tables S3, S4). The remaining instruments collected qualitative data.

4.4. Focus group

A focus group was established consisting of 5 students in the full project phase. The focus group participated actively in the project implementation. This group was convened at the beginning of the semester (18/02/2021) and at the end (14/04/2021). The focus group interviews were recorded and transcribed afterward. Furthermore, the focus group gave regular feedback by email after each class. In all the feedback moments the focus group students were asked to identify positive and negative aspects and suggestions.

4.5. Teacher diary and systematic observation

The teacher maintained a diary aimed at registering the comments on her practices, including suggestions for future changes.

Additionally, systematic observation by teacher colleagues from the university who gave written feedback was also registered for future analysis.

TABLE 1 Details of each moment that comprises a class combining TBL and SL.

Time (min)	Activity	Description
-	Pre-class activity	The pre-class activity consists of autonomous self-study. The teacher gives students an appropriate bibliography so that they can prepare for the next class. The bibliography consists of a chapter from the biochemistry book, a PowerPoint based on that chapter that might also include other details from other reference sources, and an audio file of the PowerPoint made by the teacher. While studying students can ask all their questions in Padlet which the teacher answers within 24 h.
15	Entrance into the class	The first few minutes are important for the students and professor to establish empathy and trust, and for everyone to sit close to the group members.
30	Individual questionnaire (IQ)	Students come to class already prepared and start the class with an IQ on the contents they prepared the week before; the IQ is performed online on their phones or computers and the results are saved by the professor. The IQ consists of 6 multiple-choice questions usually associated with Bloom's taxonomy level of remembering and understanding. IQ allow students to perceive if they have studied enough before class and, if doubts exist they can immediately ask the teacher.
30	Group questionnaire (GQ)	After the IQ, students start working in groups that are the same during the semester. They repeat the same questionnaire, but now they can discuss the answers with their group members. They send one response per group. At the end, the professor shows the IQ and GQ results, comparing the progression achieved in the group work. Doubts are clarified at this time.
20	Break 1	Coffee-break
40	Application activity	An application exercise is given to the group so that the group understands if they can apply the concepts learned to practical cases/case studies /…. The result is presented to the class in various formats.
20	Break 2	At this point, students are tired, and a cognitive break is welcome. A physical activity (for example, Pilates) is proposed.
20	Review and discussion	At the end, the professor clarifies in a short seminar (very interactive) the contents she felt were less clear throughout the class and ensures that no student leaves the class with unresolved questions.
5	Next class contents	The last 5 min are important to explain what students should prepare for the next class.

4.6. Content analysis

Qualitative data obtained in the full project including focus group feedback, teacher diary, systematic observation, and open feedback comments from students was subjected to content analysis through the following steps: (1) pre-analysis to understand the documents' structure and organization, which consisted of a floating reading of their content; (2) text selection operations to code the excerpts according to the predefined categories; (3) more detailed exploration of all the data, in which text was divided into units of meaning and a code was assigned to each of these units (Kuckartz, 2019; Gläser-Zikuda et al., 2020). The analysis was performed using WebQDA software[1] and a tree analysis category system was designed and implemented. Three categories were selected for content analysis: A. Strengths; B. Weaknesses; C. Suggestions.

Descriptors for content analysis were: 1. Type of Participant: 1.1 Teacher in charge; 1.2 Students; 1.3 teaching colleagues; 2. Research stage: 2.1 Before action; 2.2 During action; 2.3 Post-action (Table 4). To complete the qualitative data analysis, two researchers read the documents and selected relevant passages, coding them in the categories A, B, or C, according to the descriptors described above. Validation of the categorization process was performed by two members of the team, allowing for the standardization of the criteria used for the analysis. Once this stage was completed, the results were systematized. Frequency counts of the relevant categories and descriptors were obtained. This provided a crude overall picture of the material being analyzed. Finally, the researchers proceeded with the interpretation of content, selecting excerpts that translated the different categories.

4.7. Statistics

The quantitative data in the questionnaire response was subjected to statistical analysis performed using IBM Statistical Package for Social Sciences (SPSS), version 21.0 (IBM Corp., Armonk, NY, United States). Variables normally or not normally distributed were reported as mean and standard deviation, and median (interquartile range - 50), respectively.

5. Results

5.1. Quantitative analysis of student perception based on questionnaires

At the end of the semester, the students filled out a structured questionnaire, classifying the T and L experience. To generate a comprehensive picture of the students' perspectives, the survey combined a quantitative and qualitative approach. Each topic that was quantitatively assessed by the student included several questions related to that issue, rated on a Likert scale (1–7). Answers of "1" indicated the most negative response (completely dissatisfied), while "7" was the most positive (completely satisfied). The questionnaire

1 www.webqda.net, accessed on 23 August 2021.

from the full project included more questions than the one from the pilot. The alteration was based on the analysis of the results from the pilot study. Students were also asked to identify positive and negative aspects of their T and L experience. The qualitative part of the questionnaire will be analyzed in the section below. To assure the anonymity of students, no personal data were collected.

In the pilot study, of the 170 students, 106 answered the questionnaire (Table 5A).

From the results, it can be concluded that most students stated they were learning better with TBL + SL than with traditional classes (4,59 ± 1,86) and also that they enjoyed the activities of the SL breaks. Nevertheless, there is space for improvement since ~25% of the students considered that they did not learn better with TBL + SL than with traditional theoretical classes (they rated the question "I learn better with TBL and SL than with traditional theoretical classes" 1, 2, or 3). Also, 19 students of the 106 responders considered that the physical/manual activities in the middle of the classes were not important (they rated the question "How important were for you the physical/manual activities in the middle of the classes" 1, 2, or 3). This suggests that four classes using the implemented approach (TBL + SL) were perhaps not enough for the students to appreciate the full potential of the new pedagogical method.

Concerning the full project, from the 147 students, 45 answered the questionnaire (Table 5B). The low number of responses can be explained by the fact that the questionnaires were sent to the students to be filled out online and their fulfillment was not compulsory. In the pilot project, the questionnaires were given to the student on the day of the last exam, and they were asked to give them back at the same time they gave the exam sheet. The results from the full project suggest that the students appreciated the course as a whole. The perceptions of the students in the full project seemed to be even more satisfied than the perceptions of the students from the pilot study. This fact suggests that the slight alterations made after analyzing the negative points and suggestions of the students from the pilot study were crucial. Comparing the global question, the satisfaction increased from 4,59 ± 1,86 to 5,44 ± 1,45.

Regarding the impact of TBL, students expressed that the individual questionnaire (IQ) at the beginning of the classes was crucial to test their autonomous study (5,91 ± 1,35) and that the group questionnaire (GQ) was relevant to improve their knowledge based on peer discussion (5,89 ± 1,29). The students realized that the SL physical activity was important (5,98 ± 1,60). The existence of several assessment components did not please everyone (4,87 ± 1,51) as this was the question with the lowest evaluation. The students considered that peer evaluation was relevant for the group dynamics (5,80 ± 1,34). Additionally, the students stated that TBL random evaluation made them study throughout the semester (5,84 ± 1,09).

At our university, there is a Quality Management System (SGQ) of the T and L process that aims to improve teachers' practices by surveying the students about different aspects of their courses. This system allows us to attribute a Good Pedagogical Practice stamp to the courses which have an overall answer higher than 8 (on a scale of 1–9). In the Integrative Biochemistry course that is being addressed here, this stamp was attributed.

The SGQ questionnaire includes several questions that should be answered by all students, although this was not compulsory, which explains the $n = 50$. Here we highlighted the most relevant questions for the article and its discussion (Table 6).

Students felt that the course was organized (7,40 ± 1,75), the recommended bibliography was adequate (7,90 ± 1,48), and the assessment was fair (7,43 ± 1,81). Overall, they agreed that the course functioned well (7,51 ± 1,40). At the same time, the students stated that they required a huge amount of time working on this course to obtain final approval (8,27 ± 0,96). This aspect highlights the lack of students' knowledge of how much time should be dedicated to a discipline based on the European Credit Transfer and Accumulation System (ECTS) credits it is worth, which for the course in question, is 6 ECTS credits. Thus, 6 ECTS credits correspond to a total load of 162 h of dedication during the semester. The answers obtained from this question will allow for improvement in the following academic year by explaining in the first class how many hours they should dedicate.

The students perceived that their teacher performed well (8,16 ± 0,94) with the ability to stimulate and motivate students (8,02 ± 1,20) and they created a favorable climate for learning and active participation of students (8,33 ± 0,93). Furthermore, the teacher encouraged their autonomy (8,53 ± 0,54), while also monitoring their work (7,98 ± 1,34).

5.2. Qualitative analysis of the perceptions of the student, the teacher, and teaching colleagues

Pilot study data qualitative analysis allowed the identification of relevant aspects of the pilot project implementation. From the students' feedback analysis, improvements were possible in the full project implementation. In total, students had 63 positive highlights and 13 negative aspects (Supplementary Table S5). Overall, students stated that the positive aspects of the pilot study included the SL physical activities, the good and secure environment of the classes promoted by the teacher, and the pedagogical innovation implemented.

> *Student - "the breaks during class were extremely productive and made me concentrate more on coming back".*

> *Student – "it is a very dynamic class, in which the teacher creates an environment where we feel free both to ask questions and to be able to discuss them in a healthy way".*

In contrast, the negative aspects concentrate on the problems associated with group work.

> Student - *"having to work with people with whom I have little affinity".*

This is a common problem in every working group, not only at the university level but also professionally (Isaac and Tormey, 2015). Group work is usually not an immediately rewarding experience for students (Colbeck et al., 2015). Some students have to deal with questions of leadership, conflicts, and the egos of group members, which can become very stressful issues for students (Ford and Morice, 2003). Faculty guidance is key to dealing with group issues. Nevertheless, it is crucial to make students realize the relevance of group work to their future as professionals.

TABLE 2 Details of the assessment scheme.

Elements			%	Details
A	Test 1	Individual	30	2 individual tests on the subject taught in the middle of the semester and at the end of the semester, respectively.
B	Test 2		30	
C	Attendance		5	attendance in classes.
D	Peer assessment	Group	5	referring to the work in groups of TBL classes–a well-defined criteria table was provided (Supplementary Table S1)
E	TBL (average of 3)		15	students have several classes in TBL–3 of these were randomly selected by the teacher and were evaluated
F	Project		15	construction of metabolic maps

TABLE 3 Data collection details.

Project phases	Data collection methods	Details
Before action	Focus group interviews	Students and teacher
During action	Focus group interviews	Students and teacher
	Teachers' diary	Date; contextual information (time, location, participants); reflective notes on positive and negative critical incidents
	Systematic observation	Teachers (colleagues from the university) observation (1 - planning meeting, 2 - classroom observation, 3 - feedback discussion)
Post-action	Focus group interviews	Students and teacher
	Questionnaires	Assess students' satisfaction
		Quality Management System (SGQ)

TABLE 4 Tree analysis category system for qualitative data analysis.

Category	Descriptors		Instruments
A. Strengths B. Weaknesses C. Suggestions	1. Type of Participant	1.1 Teacher in charge	
		1.2 Students	
		1.3 Teaching colleagues	
	2. Research stage	2.1 Before action	Focal Group 1
		2.2 During action	Teacher diary
			systematic observation
		2.3 Post-action	Focal Group 2
			Quality Management System (SGQ)
			Final questionnaire

Student's feedback allowed the identification of the following aspects to be improved: (1) the need to prepare more concise content/bibliography for pre-class study; (2) the need to optimize the time spent on IQ and GQ; (3) the need to change the evaluation mode (inclusion of 2 tests in the semester); (4) the need to listen to students' opinion in the development/preparation of the course. All these aspects were taken into consideration and incorporated into the full project implementation.

Qualitative data analysis of the full project included not only the student feedback but also the opinion of the teacher and teaching colleagues. Furthermore, a deeper analysis of the content was performed in comparison to the simple analysis of the pilot study. All data from the full project used to perform the content analysis is presented in Supplementary Table S6.

An overview of the results (Table 7) allows us to conclude that from a total of 428 comments that were annotated, 53% were strengths, 26% were weaknesses, and 21% were suggestions. The students were the participants that contributed the most comments, 315 in contrast with 97 from the teacher and 16 from the teaching colleagues. Interestingly, the teaching colleagues only commented on the strength category.

5.2.1. Strengths of the full project implementation identified by the different types of participants

For each type of participant in each category, clusters were formed according to the content of each comment (Table 7). The teacher valued the positive attitude of the students toward the TBL + SL implementation and acknowledged that SL physical activities were the preferred part of the class.

> Teacher - *"In the meantime, I took a break and divided students into 2 rooms (funk and pop). I walked through the rooms, and they were chatting. Very interesting. These students barely know each other, and this is a good strategy."*.
>
> Teacher - *"The class went very well. The SL part was very good indeed. The students loved it."*.

The students were extremely enthusiastic about the pedagogical methodologies implemented. They were positively surprised by the workload and commitment of the teacher in preparing the classes.

Furthermore, they enjoyed the attitude of the teacher toward the students.

> Student - *"Some colleagues were positively surprised by the amount of work you had for the course, and the organization and complexity of it …"*.
>
> Student - *"The feedback we received, was very positive, people were very impressed with you and really enjoyed the class"*
>
> Student - *"It was the course that was a pleasure to have."*.
>
> Student - *"Very good source materials and a teacher deeply focused on our education, skills and even our lives"*.

Teaching colleagues that observed the classes highlighted the close atmosphere provided by the teacher's commitment and quick and frequent clarification of doubts and feedback to the students. Further, they acknowledged that the classes were extremely well

TABLE 5 Pilot study (A) and Full project (B) questionnaires.

Question	A. Pilot study			B. Full project		
	md	mean	Sx	md	mean	Sx
Objectives for the course						
I understand the course content	6,00	**5,52**	1,08	6,00	**5,78**	1,07
I am able to apply the course content	5,00	**5,00**	1,10	5,00	**5,29**	1,13
I have developed interpersonal and group interaction skills	5,00	**4,56**	1,60	6,00	**6,02**	1,04
I have developed skills for lifelong learning	5,00	**4,42**	1,55	6,00	**6,07**	1,04
I enjoyed the course	5,00	**5,16**	1,47	6,00	**5,82**	1,02
Impact of team based learning (TBL)						
The TBL approach was an appropriate way to structure this course	5,00	**4,76**	1,71	6,00	**5,69**	1,28
The TBL approach enhanced my learning experience in this class	5,00	**4,62**	1,58	6,00	**5,49**	1,47
With TBL, I have gained profound insights into my strengths and weaknesses as a learner	4,50	**4,31**	1,51	6,00	**5,36**	1,29
TBL enabled me to develop healthy personally rewarding relationships with the teacher	5,00	**4,44**	1,67	5,00	**5,36**	1,37
TBL enabled me to develop healthy personally rewarding relationships with my colleagues	5,00	**4,84**	1,55	6,00	**5,78**	1,21
I recommend using the TBL approach in future courses	5,00	**4,77**	1,83	6,00	**5,62**	1,40
Individual questionaries at the beginning of the class allowed me to test my study at home	6,00	**5,52**	1,46	6,00	**5,91**	1,35
Group questionnaires were important to increase my knowledge and clear up doubts with peers	6,00	**5,41**	1,53	6,00	**5,89**	1,29
Teacher feedback in the class after home studying was crucial	6,00	**5,15**	1,45	6,00	**5,80**	1,42
Impact of spaced learning						
Name writing activity	5,00	**4,44**	1,96	-	-	-
The physical activity in the middle of the classes was important	6,00	**5,13**	1,90	7,00	**5,98**	1,60
I enjoyed physical activity that included Ioga/Pilates	6,00	**5,32**	1,71	7,00	**6,13**	1,36
I enjoyed physical activity that included gymnasium workouts	6,00	**5,19**	1,87	7,00	**5,78**	1,77
I enjoyed physical activity that included some dancing	5,00	**4,95**	1,83	7,00	**6,07**	1,60
Project						
The project development was important for the development of soft skills	-	-	-	7,00	**5,89**	1,48
The project was relevant for my learning achievements within the course	-	-	-	5,00	**5,13**	1,22
Assessment						
I prefer to have several assessment components	-	-	-	5,00	**4,87**	1,51
Peer evaluation was important for group dynamic	-	-	-	6,00	**5,80**	1,34
TBL random evaluation throughout the semester made me have my study up to date	-	-	-	6,00	**5,84**	1,09
I believe that my assessment corresponded to my workload	-	-	-	6,00	**5,47**	1,44
Global						
I learn better with TBL and Spaced learning than with traditional theoretical classes	5,00	**4,59**	1,86	6,00	**5,44**	1,45

The questionnaire consists of 20 and 25 questions, respectively, that are rated from 1 to 7. In total, 106 students participated in the pilot study questionnaire response, while 45 students participated in the full project responses. n1...n7, number of answers in option 1…7; md, median; Sd, standard deviation.

designed and clear, so that, although the classes had many switches, students knew what was expected from them.

> Teaching colleague - *"The well thought out and firm (yet flexible) structure of the class, which ultimately gives structure to the students (it becomes simple to know where we are and where we are going, let's put it that way)".*

> Teaching colleague - *"The fact that you give feedback so close to the student's "performance". … we can see that you are "involved/committed", there is such a close, light, and healthy interrelationship.... What a good environment...".*

> Teaching colleague - *"Constant feedback from the teacher regarding the student's contributions, close monitoring of the student's work and the teacher's visible concern for their learning".*

> Teaching colleague - *"Your analysis of the answers to the questionnaire individually and in groups, giving space and*

TABLE 6 Results of the quality management system survey.

Question	Md	Mean	Sd
Characterization of the curricular unit			
Coordination of the various components of the curricular unit	8	7,40	1,75
Adequacy of recommended study elements and bibliography	8	7,90	1,48
Adequacy of assessment methods	8	7,43	1,81
Overall functioning of the curricular unit	8	7,51	1,40
Volume of work/time required to obtain final approval	9	8,27	0,96
Teacher performance			
Ability to stimulate and motivate students for the curricular unit	8	8,02	1,20
Creation of a favorable climate for learning and the active participation of students	9	8,33	0,93
Encouraging student autonomy	9	8,53	0,74
Monitoring student work	9	7,98	1,34
Teacher's relationship with the student	9	8,33	0,93
Global assessment of teacher performance	8	8,16	0,94

50 students participated in the questionnaire response. n1..n9 – number of answers in option 1…9; md – median; Sd – standard deviation.

TABLE 7 Frequencies of the comments in each category, detailed by type of participant.

Category	F	Descriptor 1. Type of participant	F	Clusters*	F
A. Strengths	226	1.1 Teacher	54	Satisfaction and perception of the success of implemented strategies, based on student feedback	18
				Positive perception about the motivational results of spaced learning	17
				Good time management	6
		1.2 Students	156	Positive reactions to TBL and its resources, including evaluation	51
				Positive feedback to spaced learning	41
				Overall positive feedback on the class dynamics and the teacher's attitude	27
		1.3 Teaching colleagues	16	The close atmosphere provided by the teacher's commitment and quick and frequent clarification of doubts and feedback to the students	5
				Good implementation of the TBL strategy	3
				Well-structured classes	2
B. Weaknesses	113	1.1 Teacher	25	Teacher level of effort and commitment	5
				Too much faculty time and dedication during the week	3
				Different background and study effort among students both prior to and during the semester	11
		1.2 Students	88	High workload and laborious content and other reflections on content, deficit in home study	51
				Class organization, too long class, short time to address content	11
				Problems with group work	8
		1.3 Teaching colleagues	0		
C. Suggestions	89	1.1 Teacher	18	Decisions on improvement changes, new proposals throughout the semester	7
				Requests/changes requested by students throughout the semester regarding assessment/lessons	3
				Class management	3
		1.2 Students	71	Class management	39
				TBL and its resources	9
				Feedback	7
		1.3 Teaching colleagues	0		

System for qualitative data analysis. F, frequency of comments; *The three most frequent clusters are listed.

> *encouragement for students to "move on" and explain why they got it wrong. (And there were students coming forward! Another indicator of the built-in class environment.)".*
>
> Teaching colleague - *"Overall, I really enjoyed it. You must have a lot of work preparing and following/monitoring everything, but it shows to all of us (most importantly, to your students) that you are there with immense pleasure and that you are involved in their learning, and that they are all learning together, they and you.".*

5.2.2. Weaknesses identified by the participants in the implementation of the pedagogical innovation

The flaws identified by the teacher differed from the ones pointed out by the students. The teacher recognized as the main constraint the different levels of previous knowledge of the students and the lack of weekly preparation for classes.

> Teacher - *"They had studied little; they had had tests that week"; "I notice that they are not as prepared for the IQ because they make more mistakes. It seems that they are tired."; "… These students have no background in this subject, and I had to explain it more slowly."*

The students highlighted the weekly heavy workload as the main limitation.

> Student - *"One of the points that many people pointed out and that was already discussed in the last class was the fact that the subject matter was very dense, also due to the fact that we didn't have much time to study.".*

Teaching colleagues had no weaknesses to point out.

5.2.3. Suggestions made by the participants for a next implementation round

While the activities were being implemented, during the semester (2.2 During action) the teacher identified several aspects that could be improved. The real-time student feedback on the course activities allowed the teacher to alter the planned activities so that the students could take advantage of the changes in that same semester.

> Teacher - *"Pay attention to class duration to allow me to do everything I plan";*

Amazingly, the students were great in giving suggestions about the organization of the course (2.1 Before-action), during the semester (2.2 During action), and in the final questionnaires (2.3 Post-action). The students had interesting opinions about class management, group formation, and SL.

> Student - *"I wish more time was spent on the theoretical part because I don't always understand everything just from the book. The teacher's explanations are more enlightening, and I think they are an easier, more interesting, and more dynamic way for us to learn the subject.".*
>
> Student - "*Decreasing the workload required".*
>
> Student - *"In my point of view the SL physical activity was very essential and I think there should be more sessions of relaxation techniques because they really help a lot in our daily life".*

The teaching colleagues had no suggestions to point out.

6. Discussion

This project was the first, to our knowledge, that combined TBL + SL.

We decided to apply a pilot study which was crucial for improving the implementation of the full project. The feedback from the students and the teacher, based on a final questionnaire (Supplementary Table S2) provided us with valuable information to improve the full project. For instance, students suggested that the pre-class content need to be more concise. Furthermore, they realized that it would be important to involve students at the course design level, and also during the course, so that they could benefit from the suggested changes in real time. From the questionnaire results (Table 5A) it was indeed possible to conclude that students acknowledged that they were learning better with TBL + SL than with traditional lectures, recommending the use of TBL in other courses. Additionally, the students recognized that the SL physical activities in the middle of the class were important. Also, they realized that TBL enhanced their learning experience and allowed the development of pleasant personal relationships with their teacher and classmates. Lastly, the students identified as extremely relevant the teacher's feedback in class after the home study.

The full project results clearly confirm that the T and L pedagogical innovation implemented increased students' engagement toward the course (Table 5B). Generally, the students stated that they learn better with TBL + SL than with traditional theoretical classes. Indeed, the students realized that the TBL approach permitted the recognition of strengths and weaknesses along the learning process, mainly due to the IQ, which allowed testing the home study, and that the GQ increased knowledge and cleared up doubts with peers. Additionally, the SL physical activities were crucial as a cognitive break, allowing them to resume the lesson with redoubled focus and energy.

In addition, teacher attitudes are perceived as having a high impact on student engagement. It is relevant for student engagement that the teacher's attitude and the T and L approaches are positive and motivating (Muller, 2001; Anderson et al., 2004; Klem and Connell, 2004; Roorda et al., 2011; Tang and Hu, 2022). Also, it has been shown that a positive relationship between student and teacher is important for student engagement and achievement (Roorda et al., 2011). The feedback about the teacher was highly positive. In fact, students realized the teacher's commitment to the course and the students (Table 7). The students agreed that the teacher had the ability to stimulate and motivate them, creating a favorable learning environment that encourages students' active participation and autonomy. One of the most

relevant teacher actions according to students was that the teacher constantly monitors the students' work.

Student peers, in addition to teachers, also play a key role in influencing student engagement (Zhang et al., 2019). Indeed, the students acknowledged that they developed healthy, personally rewarding relationships not only with the teacher but also with their peers. Furthermore, they considered that peers' evaluation was important for group dynamics.

Concerning the assessment, the students were more cautious about preferring several assessment components, in opposition to fewer. But they were unanimous about the relevance of the TBL random evaluation throughout the semester, which they realized keeps the study up to date. Furthermore, the students felt that the assessment was fair since they were aware it corresponded to their workload.

The accomplishment of the main objective of this study, which focused on getting the students engaged throughout the semester, has exceeded all the possible expectations. The most appreciated innovation introduced was the blend of TBL + SL. The students acknowledged different positive aspects which were crucial for their class engagement: teamwork reinforcement, improvement of their relationships with peers and teacher, and an increased eagerness to learn.

7. Conclusion

Bearing in mind that the main objective of the project presented here was to understand the impact of the implemented strategies (TBL + SL) in increasing students' engagement toward the class, it can be concluded that, indeed, it was fully achieved. The students were very enthusiastic about the course during the semester, actively participating in the classes, and studying at home prior to the class so that they could perform well in the IQ and GQ. Furthermore, they enjoyed the SL physical activities. In addition, the students felt that the teacher was committed to the course and the students and that the teacher was devoted to creating a welcoming and supportive environment for students so that they felt confident to actively participate in class. The implemented approach can be incorporated in any other course or part of a course in any study area, within large classes or smaller ones.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

VC, FR, MR, and MF: conceptualization. VC, MR, BM, and MF: data curation. MF: funding acquisition, project administration, and supervision. VC, BM, MR, LG, and MF: investigation. VC, MR, and MF: methodology. LG and MF: resources. VC, BM, and MF: writing–original draft. VC, BM, MR, LG, and MF: writing–review and editing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2023.1129763/full#supplementary-material

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