Design of a Team-Based Learning Layout for a STEM-based Seminar

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Abstract

Active learning methods are catching on in the different areas of education, as they allow students to have the active role in their education process. In this paper, an instance of active learning called Team-Based Learning has been applied in the design of a STEM-based seminar. This way, the students registered in this seminar were randomly grouped into a bunch of independent teams, where each one had to be self-managed. A complex activity was proposed to each team, which could be solved through a string of activities. The final outcome of each group was to be presented in a specific pitch presentation session. After each presentation, it had to be rated on a peer-review basis by means of a hand-made construct, which had been validated before by a panel of experts. Furthermore, the level of engagement related to the whole activity was also measured with a different construct after all presentations were done. The overall outcome achieved exhibited a high academic performance, as well as a high level of engagement.

1. Introduction

The term active learning implies the interactivity of students, such that the key points in this innovative paradigm are collaboration and exploration [1]. This way, students are expected to get more involved with the learning materials, whilst they take part in class sessions [2]. As a result of the increase in interactivity within the classroom thanks to applying an active learning approach, participation and cooperation among students are improved, which allows to better attend their learning needs [3].

Active learning techniques are often used as complementary tools in the teaching-learning process. Those tools are widely accepted by students as the use of interactive techniques as Team-Based Learning (TBL) gets students more connected with both the subjects being studied and the colleagues they are working with [4]. Furthermore, the use of active learning methods when facing problem-solving tasks, project-based assignments or role-playing activities lead to boosting the level of engagement among students. According to the literature, that enhancement of the level of engagement leads to a rise in both academic performance [5] and success rate [6].

TBL has lately become an interesting tool in order to better assimilate the concepts learned, as this technique facilitate pupils to integrate and connect contents in an attractive manner. Hence, the degree of attention is boosted, and the same happens with knowledge consolidation [7]. The application of TBL techniques within the classroom involves various aspects, such as communication, collaboration, critical thinking and problem solving. It has to be noted that the use of TBL is ever growing because it gets students engaged by posing complex problems in order to be resolved in groups [8].

TBL activities present learners with typical scenarios in working places, where teams composed of people with different background are asked to perform specific tasks [9]. This way, students are faced with situations which may not be common for them, but they surely will when they join the labor market after finishing their studies [10]. The TBL paradigm can be implemented in all educational levels, while it has been reported that the effort and time needed is worth due to the results obtained out of it [11]. TBL is considered especially beneficial in courses where a significant amount of information is provided to students in order to answer complex questions [12]. In this sense, TBL establishes a learning framework focused on solving real problems, where a small-group approach is required, as opposed to an individual approach [13].

Furthermore, a growing interest has also been reported in the application of TBL-based scenarios in interprofessional education and formative assessments [14]. The reason for this is because of the enrichment provided to students' experience when it comes to learning, contextualizing, and applying the necessary knowledge and skills to solve the issues proposed [15]. On the other hand, TBL is usually applied in on-site contexts, even though it may also be applied in online scenarios, where similar results have been reported as those found in the on-site counterparts [16].

Additionally, TBL allows instructors to readily identify the achievements of their students, which is harder to do in larger groups [17]. Hence, TBL could be seen as an instructional strategy where small

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groups are created so as to achieve an increased overall effectiveness in the learning process [18].

In this paper, a seminar devoted to providing some advanced insights related to communication in computer networks was set up with a TBL approach, where students were randomly grouped into teams in order to undertake a series of complex tasks to be solved, which eventually had to be displayed to the rest of classmates as a pitch presentation.

The rest of the paper is organized this way: Section 2 describes the method, Section 3 presents the results, Section 4 provides the discussion, and Section 5 draws the final conclusions.

2. Method

To start with, subsection 2.1 presents the main features of the seminar proposed, then, subsection 2.2 focuses on exposing the teaching/learning dimensions considered, and subsection 2.3 outlines the reasoning of the constructs used in this study.

2.1. Preamble

A seminar was set up for students in a college course on networking basics. This course was part of an engineering degree program, and it was composed of 30 students, whose ages ranged from 20 to 25. The seminar proposed was conceived as an extended activity in order for pupils to enhance their knowledge and skills in the networking field. The focus was basically set on the grounds of IP communication among network devices, even though IT configuration of end devices and cybersecurity management were also involved.

The seminar was divided into 4 sessions, where each one had different features concerning the spatial, temporal, and linguistic dimensions involved, regarding the characteristics of the teaching/learning process carried out in each specific session. The first one was set up as a masterclass, which was delivered by an expert in the field, who is teaching network fundamentals in a college located in a foreign country. Hence, the masterclass was run online and synchronous, while it was imparted in English.

Based on the masterclass received in session 1, students teamed up in groups of 3 on a random basis, such that 10 teams were conformed for the rest of sessions. This way, in session 2, each group had to undertake a team-based activity in the classroom without the time constraints of the class session, as a sort of self-managed workshop. Hence, this activity was actually an instance of TBL. Therefore, this in-class TBL activity was run in-person and asynchronous, while it was done in Spanish, which is the official language used in the course.

Afterwards, in session 3, each team had to face another team-based activity with a higher degree of difficulty than the previous one. Consequently, the class session was used just to introduce the details and the setup of the activity, so the teams had to carry out the tasks required to complete the activity beyond the classroom time. Hence, this online TBL activity was run online and asynchronous, while it was done in Spanish.

Eventually, session 4 was devoted for the different teams to expose the results of both TBL activities to the rest of their classmates in a pitch presentation format. Those presentations had a time constraint of 5 minutes, where each team had to expose what they did, how they did it, and who did it. Those presentations were delivered in English, as the teacher who gave the masterclass was invited to this session. Right after the delivery of each pitch presentation, the rest of classmates had to evaluate it on a peer review basis with a brand-new questionnaire specifically built up for this purpose.

Additionally, at the end of this session, another questionnaire was passed on to the students in order for them to assess their level of engagement during the seminar. The construct selected was the Intellectual, Social, Affective Engagement Scale, whose acronym is ISA [19]. It was originally intended to measure the employee engagement in the workplace, although its use has been extended to the academic field [20].

2.2. Teaching/Learning dimensions

Focusing on the characteristics of the four sessions exposed, it is clear that each of them presents a different combination of the values related to the location where the learning happens, the moment when the learning happens, and the language in which the learning happens. Those three features could be considered as dimensions of the learning process, which could be relabeled as space, time, and language, respectively.

If those dimensions are represented in a Cartesian coordinate system, then three mutually perpendicular axes intersect at a given point, labeled as the origin. In this context, if the values for each dimension are taken as either a traditional setup or an innovative setup, where the former is linked to the value 0 and the latter is tied to the value 1, then an overall amount of $2^3=8$ combinations are allowed, as there are 2 possible values for each of the 3 dimensions stated. Analogously, if only 2 dimensions were involved, such as space and time, the overall amount of binary combinations available would be $2^2=4$. This fact leads to the possibility of easily expressing each combination as a triplet of binary values, where the first component refers to space, the second one relates to time, and the third one is assigned to language. Besides, each triplet could be drawn as a three-coordinate point in the positive octant of a 3D Cartesian axes, namely the region where the values of all three axes are not negative, where a single unit of length is assumed for each axis, as represented in

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Figure 1.

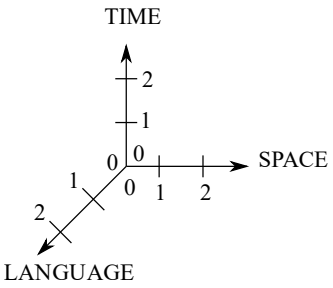

Figure 1. Positive octant tied to 3D coordinate system

Getting back to the dimensions involved in the four sessions proposed, Table 1 depicts the values for the dimensions associated to each of the sessions.

Table 1. Dimensional values for each session

Activity	Spatial	Temporal	Linguistic
Masterclass	Online	Synchronous	English
In-class TBL	In-Person	Asynchronous	Spanish
Online TBL	Online	Asynchronous	Spanish
Pitch presentation	In-Person	Synchronous	English

2.3. Coefficient of effort

It is to be noted that the triplet related to session 1 is (1,0,1). The reason for this is because the space variable took an innovative setting, as the session was held online, whereas the time variable took a traditional setting, as the session was held synchronously, and the language variable took an innovative setting, as the session was held in a foreign language.

Besides, the triplet related to session 2 is (0,1,0). The reason for that is because the space variable took a traditional setting, as the session was held on-site, whilst the time variable took an innovative setting, as the session was held asynchronously, and the language variable took a traditional setting, as the session was held in a local language.

Moreover, the triplet related to session 3 is (1,1,0). The reason for that is because the space variable took an innovative setting, as the session was held online, while the time variable took an innovative setting, as the session was held asynchronously, and the language variable took a traditional setting, as the session was held in a local language.

Eventually, the triplet related to session 4 is (0,0,1). The reason for that is because the space variable took a traditional setting, as the session was held on-site, while the time variable took a traditional setting, as the session was held synchronously, and the language variable took an innovative setting, as the session was held in a foreign language.

On the other hand, it is to be considered that the triplets are composed of binary values, where the value 0 stands for a traditional setting and the value 1 does for an innovative setting. Furthermore, it is to be noted that a value of 1 in any of the variables, namely space, time, or language, implies an extra effort for an instructor to set up a session, as it represents moving away from the usual settings associated to traditional sessions, which are identified with a value of 0.

Hence, a sort of 'coefficient of effort' could be established in order to account for the relative difficulty to set up an innovative session. The easiest way to calculate this coefficient would be to add up all components within a triplet. The result would be a natural number ranging from 0 to n, which would represent the number of variables taken into account.

This way, if the coefficient of effort is 0, then it represents a traditional setting, such that all variables are worth 0. On the other hand, if the coefficient of effort is n, then it represents an innovative setting for all variables at the same time. Otherwise, any other natural number between 0 and n could be obtained, depending on how many variables take an innovative value for a particular session.

This version of the coefficient of effort could be identified as plain. If this approach is taken, then the values related to it for the sessions proposed would can be easily calculated. This way, the first session proposed is identified by triplet (1,0,1), thus its plain coefficient of effort would be 1+0+1=2. Besides, the second session proposed is identified by triplet (0,1,0), hence its plain coefficient of effort would be 0+1+0=1. Moreover, the third session proposed is identified by triplet (1,1,0), so its plain coefficient of effort would be 1+1+0=2. Finally, the fourth session proposed is identified by triplet (0,0,1), thus its plain coefficient of effort would be 0+0+1=1.

Taking the values obtained for the plain coefficient of effort, it happens that sessions 1 and 3 have a value of 2, whereas sessions 2 and 4 have a value of 1. Hence, it could be concluded that sessions 1 and 3 require more effort to set them up and run them if they are compared to session 2 and 4. Furthermore, a session with all three variables taking the innovative value would account for a plain coefficient of effort 1+1+1=3, such that it would require the highest effort to be set up and run. On the contrary, a session with all three variables having the traditional value would stand for a plain coefficient of effort 0+0+0=0, such that it would require the lowest effort to be set up and run.

On the other hand, the plain version of the coefficient of effort assigns the same weight to each of the variables considered, which are space, time, and language. However, different weights could be assigned to each individual variable in order to account for the relative effort needed to undertake an innovative setting, as opposed to a traditional setting. In this context, specific measurements should be made

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in order to properly calibrate the effort implied for each innovative setting. This may lead to the definition of a weighted coefficient of effort, which may measure in a more precise manner the potential difficulty of managing the different innovative settings in a given session.

Nonetheless, a weighting system would assign a generic value of α for online classes, which is the innovative setting for the space variable, whilst a value of β could be assigned for asynchronous classes, which is the innovative setting for the time variable, while a value of γ might be assigned for foreign language, which is the innovative setting for the language variable. In this way, the weighted coefficient of effort could be expressed in terms of a combination of α, β, and γ, which could represent a more accurate measurement than the plain coefficient of effort, depending on how precise is the value of such coefficients related to the effort associated to establish a given innovative setting.

A possible approach for the weighted system would be to assign values of α, β, and γ around one unit, such that there should not be a huge difference between the plain version and its weighted counterpart. However, further research must be done in this specific topic in order to come up with an accurate value for those weights, namely α, β, and γ.

2.4. Constructs used

There are two constructs needed, as one is geared for students to carry out the evaluation of the pitch presentations on a peer review basis and the other one is aimed at measuring the level of engagement of students. Regarding the former, it is to be considered that this questionnaire is brand-new, so it is necessary to first validate the items included, and this validation process must be made by a panel of experts. Hence, the items proposed have to be included in a questionnaire aimed to the panel of experts, and if validation is achieved, then those items will be ready to be included in another questionnaire to be passed to the students.

Regarding the latter, it is to be noted that the ISA questionnaire has been around since 2012, so its items have been previously validated. This construct is composed of 9 items, which are equally distributed into 3 dimensions, namely 3 items per dimension. Those dimensions are in fact Intellectual, Social, and Affective, and that is where the acronym ISA comes from. As a side note, this construct was designed for working environments, even though it is often used in educational environments.

In summary, there are three constructs involved, such that two constructs are used in order to evaluate the results of the students in the seminar, and another construct is used to assess the engagement and motivation of the students.

With respect to the first one, it is composed of a bunch of items to be rated with 4-point Likert-type scales to be filled in by the members of a panel of experts. In fact, each item is rated according to two dimensions, namely the construction of the item and its clarity, and the average outcome is used to calculate the Aiken's V test. This way, if the value obtained is above the Aiken's benchmark, then the items within the construct get validated, or otherwise, the items with the lowest scores are dropped out until the Aiken's V test for the remaining items gets passed.

With regards to the second one, it is composed of the items previously validated by the panel of experts. However, those items are to be rated with 5-point Likert-type scales and must be filled in by the students in order to evaluate the pitch presentation of each team. Concerning the third one, it is composed of nine items to be rated with 7-point Likert-type scales by the students in order to measure their level of engagement after having carried out the seminar.

3. Results

To start with, the first construct was built up in a clean slate manner, such that 6 items were proposed in order to evaluate the presentation based on the TBL on a peer review basis. Those items were evenly grouped into two categories, such as configuration and communication, were the former refers to the setup of the scenario proposed, and the latter relates to the delivery of the pitch presentation.

Table 2 exhibits those 6 items, along with the corresponding categories they are grouped into. Specifically, the elements related to configuration are IP, IT, and cybersecurity, whereas the elements tied to communication are functionality of the configuration applied, execution of a proof of concept, and communication skills.

Table 2. Items proposed for peer-review assessment

Categories	ID	Item
Configuration	Q1	IP configuration
	Q2	IT configuration
	Q3	Cybersecurity
Communication	Q4	Functionality
	Q5	Execution
	Q6	Communication skills

The validation of those 6 items was carried out by means of the Aiken's V test. For this matter, a construct with those items was forwarded on to 5 experts in the field in order to rate each item in a 4-point Likert-type scale according to 2 dimensions, namely, the construction and the clarity of each item. Table 3 displays the outcome of the Aiken's V test, where the acronym AVG stands for the average of all ratings obtained in a given item and dimension. As the result obtained in the Aiken's V test is higher than the benchmark established for this test, which is

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Table 3. Aiken's V test for validating the items

	Construction	Clarity
AVG Q1	3.6	3.8
AVG Q2	3.8	3.8
AVG Q3	3.6	3.4
AVG Q4	3.8	3.6
AVG Q5	4.0	3.8
AVG Q6	4.0	4.0
AVG for each DIMENSION	3.80	3.73
AVG for whole CONSTRUCT	3.77	
AIKEN'S V TEST	0.92	

0.87, then it can be concluded that the construct composed of those 6 items has been validated by the panel of experts. Therefore, the construct is ready to be delivered to the students in order for them to evaluate the pitch presentations on a peer-review basis.

In the session dedicated to pitch presentations, all students had to rate each of those presentations with the construct previously validated, where each item was to be rated in a 5-point Likert-type scale. Table 4 exposes the centralization and dispersion statistics related to the outcome obtained, where the results have been grouped into configuration and communication, as well as the overall results.

Table 4. Descriptive statistics of peer-review rating

Statistics	Configuration	Commun.	Overall
Average	4.62	4.32	4.47
Mode	5	4	5
25^{th} Percentile	4	4	4
Median	5	4	4
75^{th} Percentile	5	5	5
Variance	0.28	0.40	0.37
Standard Deviation	0.53	0.63	0.61
Coefficient ofVariation	0.11	0.15	0.13

Furthermore, the reliability of the results obtained was calculated through the Cronbach's Alpha. Table 5 depicts the outcome considering the results under configuration and communication, as well as overall.

Table 5. Cronbach's Alpha of the peer-review rating

Configuration	Communication	Overall
0.73	0.87	0.85

As the overall outcome is above 0.7, the results can be considered as reliable, which implies internal consistency as well as high correlation. Nonetheless, in order to double check the latter, the correlation has also been measured through both the Pearson's correlation coefficient and the Spearman's rank correlation coefficient, as shown in Table 6.

Table 6. Correlation degree of the peer-review rating

Pearson's correlation coefficient	0.59
Spearman's rank correlation coefficient	0.55

After all presentations were done, a further construct was delivered in order for all students to rate their level of engagement during the TBL activity. This was done through the ISA engagement scale, whose items are exhibited in Table 7.

Table 7. The ISA engagement scale

Dimensions	Items
Intellectual Engagement	I focus hard on my work.
	I concentrate on my work.
	I pay a lot of attention to my work.
Social Engagement	I share the same work values as my colleagues.
	I share the same work goals as my colleagues.
	I share the same work attitudes as my colleagues.
Affective Engagement	I feel positive about my work.
	I feel energetic about my work.
	I am enthusiastic in my work.

Each of those elements had to be rated in a 7-point Likert-type scale. Table 8 exhibits the centralization and dispersion statistics related to the outcome obtained, where the results has been grouped into intellectual, social, and affective, as well as the overall results.

Table 8. Descriptive statistics of engagement level

Statistics	Intell.	Soc.	Affect.	Overall
Average	6.47	6.58	6.61	6.56
Mode	7	7	7	7
25^{th} Percentile	6	6	6	6
Median	7	7	7	7
75^{th} Percentile	7	7	7	7
Variance	0.54	0.47	0.31	0.44
Standard Deviation	0.74	0.69	0.55	0.66
Coefficient ofVariation	0.11	0.10	0.08	0.10

Additionally, the reliability of those results was found out by means of the Cronbach's Alpha. Table 9 displays the outcome considering the ratings grouped into intellectual, social, and affective, as well as overall.

Table 9. Cronbach's alpha of engagement level

Intellectual	Social	Affective	Overall
0.85	0.83	0.87	0.84

4. Discussion

The aim of the first construct in this study,

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presented to a panel of 5 experts in the field, was to validate a set of 6 items for peer reviewing a TBL activity. Those items were grouped into 2 categories, namely configuration and communication, such that each category was composed of 3 items each. This construct was composed of 2 dimensions, namely construction of the item and clarity of the item, hence each item had to be rated in both dimensions by means of a 4-point Likert-type scale.

The results obtained were used to calculate the Aiken's V test, whose outcome was 0.92. The target of this test is to overcome a benchmark in order to consider the items within the construct as validated. Different benchmarks have been proposed in the literature, where a higher value corresponds to a tighter agreement among judges and a lower value stands for a looser agreement among them.

The most common benchmarks in the literature are 0.87 proposed by Aiken [21], 0.70 proposed by Charter [22], and 0.50 proposed by Cicchetti [23]. The benchmark selected was the higher one, although the value obtained in the Aiken's V test was higher, as it was 0.92. Therefore, the items being part of the construct were validated.

The aim of the second construct was to evaluate students about the TBL activity with the 6 items previously validated by the panel of experts. Hence, each of those items had to be evaluated by means of a 5-point Likert-type scale. The categories established in the first construct were considered as the dimensions of this construct, such that the results were aggregated according to those dimensions, as well as overall.

Descriptive statistics were applied to the aggregated results obtained, where centralization statistics showed values around 4.5 out of 5, whereas dispersion statistics exposed values slightly lower than 0.15 for the coefficients of variation [24]. The former is clearly a high value, as it is quite close to the top value, whereas the latter indicates low variability of the results, as that value is considered as the boundary of moderate variability [25].

Furthermore, the centralization average value achieved for the configuration dimension was higher than its communication counterpart, which indicates that students are more confident with technical skills than with soft skills. This is a common feature in STEM-related students, which is the case herein.

Moreover, the Cronbach's Alpha was applied to the overall results obtained, as well as to the aggregated results per dimension. In the overall case, the value achieved was 0.85, which is the interval of good reliability, as it is between 0.8 and 0.9. On the other hand, in the aggregate results, the value achieved for configuration was 0.73, which is in the interval of acceptable reliability, as it is between 0.7 and 0.8, whereas the value achieved for communication was 0.87, which is in the interval of good reliability, but close to the excellent range [26].

Reliable results also imply high correlation, which was double checked by calculating the Pearson's correlation coefficient and the Spearman's rank correlation coefficient [27]. Both of them are aimed at measuring the correlation among two sets of values. However, the former measures the linear correlation among them, whilst the latter measures the monotonic correlation among them. Anyway, both coefficients were above 0.50, which accounts for a high correlation between the two sets [28].

The aim of the third construct is to assess the level of engagement of the students while undertaking the TBL activity. This construct is the ISA, which has been widely reported and studied in the literature [29], so it was not necessary to validate the items included as it was done during its design. Those items had to be assessed through a series of 7-point Likert-type scale, while the threshold to consider a high engagement level is 6, taking into account the average of all ratings for all items [30].

We also applied descriptive statistics to the results aggregated by dimensions and overall. The dimensions considered in this construct were intellectual, social, and affective. Regarding the centralization statistics, the average values were around 6.5 out of 7, whilst regarding dispersion statistics, the coefficients of variation attained were slightly lower than 0.10. The former is a high value, as it is close to the top value, and it is obviously higher than 6, which is considered as the benchmark for high engagement, whereas the latter shows a low variability of the results, because it is below 0.15, which is the benchmark for moderate variability.

Besides, the Cronbach's Alpha was also calculated for those results, aggregated by dimensions and overall, which accounted for values around 0.85. Those values are all in the range between 0.80 and 0.90, which represents a good reliability of the outcome obtained. Consequently, the reliability of the results imply internal consistency as well as high correlation, which was expected according to the high scores achieved.

Additionally, the level of engagement is related to the degree of motivation from the students [31], such that it is widely reported in the literature that a high level of engagement is usually tied to an increase in both academic performance and success rate [32]. Therefore, it can be concluded that the high level of engagement experienced in this study led to rise the academic performance and the success rate [33].

5. Conclusions

In this paper, a TBL activity has been presented in the context of a college course devoted to networking fundamentals. This activity was deployed into four sessions, where different settings related to space, time, and language were assigned to each session. The first feature involved the location were the learning

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took place, either in-class or online. The second feature involved the moment were the learning took place, either synchronous or asynchronous. The third feature involved the language in which the learning took place, either in local language or in foreign language.

The last session involved a pitch presentation were the different teams within the class had to expose the results of the TBL activity proposed. After each presentation, all students had to rate it with a specific construct on a peer review manner, whereas a further construct was delivered at the end of the session in order to rate the level of engagement while carrying out the TBL activity.

In order to do so, three constructs were used. The first one was aimed at a panel of 5 experts in the field in order to validate the items within the construct for peer review. Hence, the target was to get the construct validated before the session when the students undertook the pitch presentations and the peer review ratings.

The second one was aimed at students in the session dedicated to deliver the presentations in order for them to rate each presentation on a peer review basis. Hence, this construct was passed on to the students after each presentation.

The third one was aimed at students in order to rate their level of engagement during the TBL activity. Hence, this construct was passed on to the students just at the end of the session dedicated to deliver the presentations.

The results obtained by the students exhibit a high academic performance, as well as a high level of engagement, because the average scores are close to the top marks with a low variability in all constructs filled in by the students. Therefore, it confirms the point made in the literature that a high level of engagement usually involves a high academic performance.

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