

## **A PBL Experience to Simulate a Business Environment in a discipline of Chemical Engineering Course**

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### **INTRODUCTION**

The engineering courses in the XXI century are facing a double challenge; they must deal with the high velocity of technological changes and, at the same time, they must produce engineers with skills that some years ago were acquired from the professional experience, such as capacity of team work, leadership, communication and expression. These abilities are being called as transversal skills [1].

Important studies associating the knowledge retention rate to the teaching method have reported that traditional classes present average rates of retention of only 5%, while discussion groups, practice by doing and teach others to do respectively show average rates of 50%, 75% and 90% [2,3]. Thus, it is clear that traditional forms of education, although still widely practiced, do not reach the expected role to the XXI century education.

In addition, since 1960, many studies had already been published about new methodologies that were able to make the students have greater retention of knowledge while they developed very desirable skills for a professional [4,5]. Among these new teaching methods, the one which was called Project-Based Learning (PBL) has become well known and used. The term PBL was originally used by Don Woods, based on his work at the Chemistry course at McMaster University in Canada, but it only took international dimension after it was applied in the School of Medicine of the same University [6]. However, some authors attribute the origins of

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PBL to 1900, when the American philosopher John Dewey demonstrated the "learn by doing" [7].

The PBL method stands out for having the student as central and main figure in the learning process and, according to Lima [8], to focus on the student and its performance in order to acquire the skills defined in the planning of the process. According to Campos [9], the main characteristics of the method are: to have the student as the centre of the process; the development of the project in tutorial groups and to be an active, cooperative and interdisciplinary process.

Thus, PBL methods seem to be a reasonable tool to promote the acquirement of those transversal abilities at the same time that it helps to overcome some difficulties to deal with students that expect much more than traditional courses can provide.

In this work, the authors show how an experience, based on PBL principals, was used to simulate a business environment to the students of a discipline called Industrial Chemical Processes aiming at the same time to promote the learning of matters related to the discipline and the acquisition of some skills needed to the engineering professionals.

## **1 THE METHOD**

### **1.1 The discipline**

The discipline chosen to perform this experience is called Industrial Chemical Processes II. It is placed at the eighth semester of a ten semesters syllabus of the Chemical Engineering course at School of Engineering of Lorena, a unit of the University of São Paulo in Brazil. It is not a discipline of the main core of the syllabus, but it is important because it improves the overview that the student has on chemical engineering knowledge areas.

The program of the discipline consists of six themes: pulp and paper industries; sugar industry; alcohol industry; biotechnology industries; technology of fats and oils and manufacture of soaps and detergents. Its objective is to provide students with a current view of industrial processes that use chemical or biochemical conversion as a route of transformation of raw materials into products.

Up to now, the discipline was taught with traditional teaching method, that is, the professor prepared lessons in slides and passed the information to the students that studied the written material distributed. They were evaluated through two written tests.

### **1.2 The new proposal**

The new proposal to the course was based on a PBL approach. The class was divided in groups. Each two groups were supposed to work on the same theme (their project) and they would compete against each other. The group should act as if it were a start-up company; the rest of the class should act as if they were investors, who should define what "company" would receive more investment.

The basic rules of the "game" were announced on the first day, after a motivational speech on the PBL method and its benefits to the learning process.

The experience was conducted on the second semester of 2014, when the class of the discipline had 66 students. They were divided into twelve groups, so that every two groups received one of the six themes of the program.

### 1.3 The 13 rules

The rules that would regulate all the procedure to be followed in the semester have been compiled on 13 items, described in *Table 1*.

*Table 1.* The 13 main rules

1	The course will be based on a PBL approach, thus, all program content will be viewed by students within a scheme in which you will have to "get your hands dirty."
2	The central idea is that there will be working groups that will act as start-up companies that will present projects to investors.
3	The class will be divided into 12 groups. The definition of the components of each group will be made by the professors, by drawing lots. The groups will have 5 or 6 students.
4	Each two groups will work on one of the following themes: <ol style="list-style-type: none"> <li>1. pulp and paper industries</li> <li>2. sugar industry</li> <li>3. alcohol industry</li> <li>4. biotechnology industries</li> <li>5. technology of fats and oils</li> <li>6. manufacture of soaps and detergents</li> </ol>
5	Each group will have the following positions: Manager, reporter, spokesman and co-workers.
6	The groups compete with each other in pairs, that is, a group has as an opponent the one who works on the same theme.
7	There will be a presentation schedule, divided into two blocks of six weeks each. In the first stage, each group will present their area of knowledge, in the second; it will present a specific problem and its innovative solution for it.
8	Each group should prepare an "investment proposal" in its area of expertise to convince investors to allocate funds to the project. Since investors know nothing about the matter, you must first let them know the context of the subject; then you need to present the innovative idea to be implemented, containing study of technical and economic feasibility and possible environmental impacts.
9	The investors are the students (except, of course, the assessed team and its opponent), so that the students decide what percentage of the available resources will be allocated to which project. The amount of available resources is imaginary and should be set in percentage terms for each team.
10	Each presentation must include: <ol style="list-style-type: none"> <li>1. A text, delivered on the day of the presentation in PDF format;</li> <li>2. A slideshow of up to 15 minutes;</li> </ol> After each presentation, the opposing team will do a question to the presenting team. The team has five minutes to formulate and present the answer.
11	In the week between the two blocks of presentation, the groups may reorganize changing positions of each member. Each group may, only in this week, dismiss a member of the group, which will be "unemployed" and may get "job" in another group (provided that there is a place in it). The firing and admission must occur by majority vote of the members of the group. To a member of the group is also possible to fire himself, which also leads him to the condition of "unemployed".
12	Students who remain in the condition of "unemployed" will have its grades calculated by the normal rule of assessment of the discipline, that is, two written tests, made in the middle and in the end of the semester. The subject of the tests will correspond to the content of the presentations made until the evaluation date.
13	Any additional demands and needs in order to enable the course to be applied properly will be adjusted during the semester by the professors.

### 1.4 The composition of individual scores

Also on the first day of the course, the rule of composition of individual scores was shown to the students, thus everyone knew how they would be evaluated and how their score in the discipline would be calculated.

The students had two grades in the semester, corresponding to the grades of the two written tests of the regular rule of the discipline. These grades were called as  $P_1$  and  $P_2$  and were calculated according to the equation (1)

$$P_x = G_{invest} + G_{att} + G_{peer} + G_{prof} \quad (1)$$

Where  $G_{invest}$  is the average of the investment received by the group,  $G_{att}$  is a grade proportional to the attendance on the classes (presentations),  $G_{peer}$  is the peer assessment of the student (attributed by its group) and  $G_{prof}$  is the grade attributed to the group by the professors. The rule for each grade is shown in *Table 2*.

*Table 2.* The rule of composition of individual scores

Investment (G)	From 0 to 4 points (proportional to the investment)
Attendance in activities (I)	Up to 2 points (proportional to the amount of attendance)
Peer-assessment in the group (I)	Up to 2 points (specific rule)
Overall score - Professors (G)	From 0 to 4 points

(G) – Group (I) – Individual / Note. The sum cannot exceed 10!

As it can be seen in *Table 2*, if all the grades are the highest, the sum is 12, but our maximum score is 10; this was intentional, because in case both opponent groups were very good and balanced and had their investment divided in 50% for each, the grade of the professors could compensate a possibly unfair grade, making possible the highest score (10) to the student.

After each presentation all the “investors” received a card with statements about the quality of presentation, with responses scaled between strongly disagree and fully agree, according to the Likert scale [10], as it can be seen in *Table 3*. They had to fulfill the card with the investment grade, in percentage.

*Table 3.* Evaluation and investment card

Statement	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
The presentation was appropriate to the subject					
Presenters demonstrated to have adequately prepared to pass on their knowledge to you					
The topics of the presentation were well organized					
The oral presentation was clear					
The presenter made good use computational and audio-visual resources available					
The presenter made good use of time for presentation					
In the question section, the group presented their arguments clearly and rationally					
The presentation contributed to your learning					
The presentation sparked your interest to study more about it					
The presentation convinced you to invest in this company					
Knowing that there are two companies presenting on the same subject and you should invest all your resources in both and, based on your answers above, what percentage of your resources you decided to invest in this company?	Group A__%				

The peer-assessment in the group had a specific rule. The group should attribute a grade for each member, according to the possible notes that are described in *Table 4*, so that the sum of the grades of the group result zero. Each grade corresponds to a number of points that contribute to the score of each student. The idea was to force the group to rank the quality of participation of each member.

*Table 4.* Range of possible grades in peer-assessment

Possible Grades	Points
-2	0
-1	0,5
0	1
1	1,5
2	2

All the control of the process was implemented using Excel worksheets where the professors noted every week the presence, the investment given by each student to the groups and his own grade to each group. At the end of each six weeks of presentation, they collected the peer assessment grades and the  $P_x$  grade was calculated and published.

## 2 RESULTS AND DISCUSSION

### 2.1 The presentation environment

On the second week of the semester the presentations were started. The first important behavioural point observed was the language used by the presenters; they have immediately grasped the idea of the business environment and they have addressed to the class as if they were talking to possible interested in their business, not as speaking to classmates, using a more formal language than that used colloquially.

The competition environment has brought seriousness to the process. It was observed that most teams have worked well in their presentations, trying to convince colleagues that their "companies" knew enough about the subject they worked.

The frequency in the classes was high, averaging 90% attendance at all sessions. Obviously a lot of this was due to the fact that part of the grade (up to two points) was proportional to the frequency, but the active participation of students in presentations could be observed in several occasions, with students asking questions and comments to presentations that did not concern with their specific themes.

### 2.2 Corrections in some rules

Over the first few weeks of work, some corrections had to be made in the rules to adjust the methodology to the proposed objectives for the course. Among them, stand out the following:

- Each week, two groups presented their work based on the fundamentals of their theme, and then the opponent team formulated their question to the group. Although the objective of this procedure was to show the "investors" the knowledge of the group on its subject, some opponent teams started to formulate questions as real traps, aiming to put the presenters in a difficult situation. So the professors started to judge questions before they were proposed and when they observed the destructive intention in some question, they asked the group to reformulate it.
- After a few weeks of work, it could be noticed some interesting facts on the behaviour of students. The main fact to be reported is that about the popularity of some individuals, who began lobbying for more invest in their companies, regardless of the presentation quality.

This fact could be noticed when the professors noticed a discrepancy between their evaluation and the investment obtained by a group that had poorly presented the work. To eliminate the suspicion, the professors called some students to talk privately and asked if there was anything abnormal in the allocation of investment for that particular group. Then some students revealed that a group member, a very charismatic person, had asked colleagues to invest more in his group.

Despite considering a serious fact, the case was seen as due to the competitive environment that has been created, which has a whole positive aspect for promoting the quality of work, but, on the other hand, also has a negative side which can lead to less ethical attitudes like that.

The means employed to correct this problem was to introduce an adjustment factor in the investment grade for each student. This factor was calculated according to the success of their investments in groups who obtained higher average investments, ie, if the student systematically invested in groups that had low average investment, the factor would be less than one and his investment note would decrease slightly, but if the student invested in the best-evaluated groups, the factor would be greater than one and his investment note would increase slightly. So, equation (1) was adapted to equation (2). After this change of rule, no more discrepancies were observed between the class average investments and professors' grades.

$$P_x = G_{invest} \times f_{ret} + G_{att} + G_{peer} + G_{prof} \quad (2)$$

Where  $f_{ret}$  is the factor of return on investment.

- Other correction that was necessary was related to the peer assessment grade. At the end of the first block of presentations, all the groups were instructed to rank their members according to the rule of peer assessment described in *Table 4*. But, 10 of 12 groups attributed the grade zero to everyone, what did not break the rule, but neither ranked the quality of the participation of each group member. So, for the next assessment it was prohibited zero attribution for all group members.

### 2.3 Transversal Skills observed

By working in groups with their organizational structure and leaders, students had the opportunity to exercise leadership and communication skills, sense of organization and responsibility for meeting schedules. The creativity and proactivity are other skills that have come with the PBL, since learning was centered on the student, who became the main actor in the process of acquisition and manipulation of information. With the presentations to the classmates, students exercised the ability to assemble a clear and succinct presentation, besides the control of time, a great difficult for those who are still inexperienced.

The management of internal conflicts in groups can also be highlighted as one of the skills exercised during the course, as on several occasions groups came to the professors to bring problems such as: a member who does not work, a member who wants to do everything by himself, a member who wants to fire himself to work with another group, etc. In all these cases, the professors' guidance was always in the sense that the problems should be resolved as if they were acting in a company, i.e. targeting the company's interests and not the particular interests of each member.

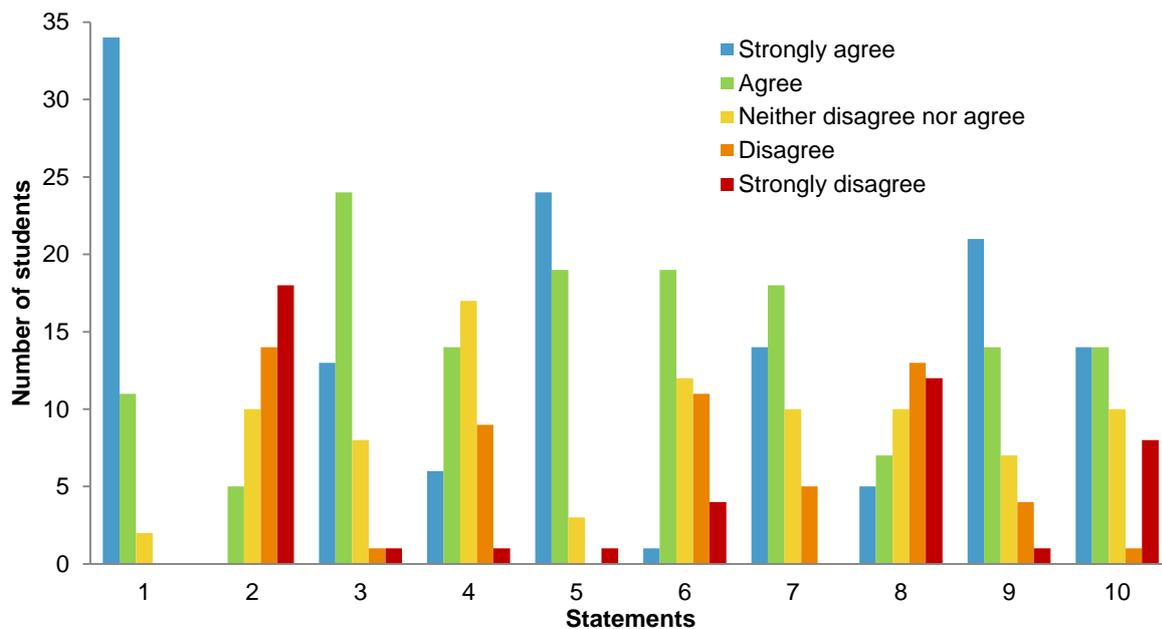
Thus, it can be said that many of the transversal skills desired to the engineer were created and/or exercised during the course.

## 2.4 Self-evaluation of the course by participating students

In order to have a feedback from students about the methodology to which they had been submitted and to evaluate the acceptance of the method by students and also to understand to what extent the method contributes to the formation of the student, a survey was completed by the whole class on the last day of the course. The survey consisted of statements to be classified according to the Likert scale. The statements are described in *Table 5*. The answers to the survey are compiled in *Figure 1*.

*Table 5. Statements to be evaluated by the students*

Statements	
1	The methodology used in this course is innovative
2	I think the learning method has brought losses to my learning
3	This way used in teaching the discipline was more motivating than the traditional way
4	This way used in the course of teaching resulted in a higher workload than the traditional way
5	I have reached to learn very well the subjects concerned to my group
6	I have reached to learn very well the subjects concerned to the other groups
7	I consider that the criteria for evaluation (grades) were righteous
8	There have been many attempts to circumvent the rules by the students
9	I wish more disciplines were taught this way
10	The competitive environment contributes to motivating the learning



*Fig. 1. Compilation of the answers to the questionnaire in Table 5*

The results of the survey show that most students consider that, although it is an innovative and more motivating method than traditional one, it did not bring losses to their learning. In addition, students consider that the course has a workload equivalent to the traditional course, which may contradict the tendency to think that these methodologies relieve students' workload.

Analysing the answers to statements 5 and 6, it was observed that the students could better learn the items related to the subject of their work group than other matters, even considering that everybody had accessed all subjects through the critical analysis they needed to do to the work of other teams while acting as investors. This may be the most imperfect point of this experience and would be an aspect to be revised to a forthcoming experience.

In general, students considered the evaluation criteria were fair, and would like more disciplines were taught according to the PBL method.

### 3 CONCLUSIONS

This paper reports an experience of the application of PBL method in a discipline the course of Chemical Engineering.

The rules created to conduct the experiment allowed the professors to simulate a business environment so that the students felt as if they were acting in their professional lives.

The solution of conflicts of interest and the achievement of goals and deadlines allowed students develop important skills for their future professional activities while they learned the content of the syllabus.

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