PROBLEM-BASED LEARNING AS TOOL TO INCREASE LEARNING AT INDUSTRIAL ENGINEERING EDUCATION: A CASE STUDY BASED ON THE PERCEPTION MEASUREMENT OF STUDENTS IN THE CLASSROOM OF COSTS MANAGEMENT.

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This paper aims to bring forward the results of a perception research during the application of Problem-based learning (PBL) into an undergraduate program of Industrial Engineering and Operational Management (as well known as Production Engineering) the State of Para. The arguments for considering PBL as suitable teaching resource rely on the existence of multiple barriers and obstacles impeding effective learning of the discipline Costs Management, including the following: a) High level of failures were traditional concerning to this subject (22,8%) b)The approach was applied on a class students who had failed at Costs Management and who were taking the subject for the second time in 2010; (c) Learners’ lack of experience with formal Costs Management techniques; (d) Low interest or confidence in taking part in theoretical classes. Therefore, considering specific characteristics of such environment, it is proposed in this paper a case study for designing PBL teaching approach at the Engineering Education aiming to improve the overall management skills of senior students in solving practical problems and taking decisions, and yet to establish new practices to increase students performances at Costs Management studies through the implementation of real problems into the learning environmental. Then, it was applied through survey a comparative students’ perception research of the traditional method and the PBL applied in classroom concerning to three specific issues: i) Learning; ii) Professor’s role and; iii) Discipline Contents. Finally, this paper also provides to Industrial Engineering teachers comments on how to handle PBL process and techniques effectively.
Palavras-chaves: Teaching Engineering, PBL approach, perception research, Engineering Education, transferable skills
1. Introduction

Although it is widely known that students are extremely important agents in the education process, in most classrooms, they are still considered passive elements of learning. In other words, in many educational approaches, students’ role is not currently set to be active and involved into learning and research. Yet it is not uncommon to find full University classrooms where students have contents presented without any update. In addition, the approaches to measures that passively acquired knowledge are not more creative: they are performed through theoretical tests where memorization of given concepts are considered more important than optimizing the capacity to solve real problems.

One other important situation to elucidate is that students at age 18 to 25 have larger access to information through the efficient use of Internet. Therefore, they might easily stand bored when they cannot identify applications to the content in transference during a class. One possible cause to this fact is that job opportunities are not only prospecting professional with high technological and management skills; they are demanded to possess innovative and participative abilities.

In the specific case of Industrial Engineering and Operational Management education, which is also known as Production Engineering that may represent a critical issue that must be increased, as the nature of this course is defined by its social and Technique frameworks (MÁSCULO, 2009). That means that education with quality in this area requires that the class content to be shaped according to both the technological reality and the social demands for professionals able to propose responsible technical solutions to daily operational problems.

The course of Production Engineering at the University of the State of Para (UEPA) is considered a reference in the North Region of Brazil as it has accomplished two times the grade 4 at the National Examination of Students’ Performance (ENADE). After completing twelve years of functioning, UEPA has graduated over 250 students in this area.

Although the consistent history of education in this institution, where there have been produced numerous papers, research projects and yet national wards at activities related to under graduation education, at the end of the course, subjects as the Costs Management have been motive of wide apprehension among professors as well as among students. The reason to this may be explained for the high taxes of unsuccessful attempts of approbation at similar quantitative disciplines - in 2009, failures reached the mark of 22,8% for Costs Management. (OLIVEIRA, 2009). A further investigation over of this occurrence has shown the possibility of an improvement opportunity to be applied on subject Costs Management: the use of the Problem-Based Learning as a tool to improve students’ experience in this subject.

Therefore, considering the exposed context above, case study was constructed with measures of the level of satisfaction and performance of students who have experienced two styles of classes for the same discipline:

a) The first experience of the group was concerned to the regular expositive classes where the content was presented with high charge of theoretical exercises. As results part of the group has failed at the subject in the year 2009;

b) The second experience has involved the Problem-Based Learning Approach at the year 2010, when the same students have been introduced to a new style of classes, where the proposed problems were actually real samples of the reality of the local industries.
Then considering this effective change into the education approach of the discipline Costs Management and in order to offer the students the opportunities to take a course where practical elements and solving real problems are present and where those elements facilitate the development of creative skills to support decision, the Problem-Based Learning (PBL) was implemented. This paper presents the results of an investigation on Engineering Education considering the improvement acquired in classroom by the introduction of the Problem-Based Learning into a five students group in the State of Para.

2. Problem-Based Learning (PBL): Concepts and Applications

First established in the 1960’s and applied on medicine courses, problem-based learning is a new method of teaching that achieved significant approval, and since then it has been object of studies to evaluate its new features and analyze its adaptability to other undergraduate courses as well. “Problem-based learning has now become a widespread teaching method in disciplines where students must learn to apply knowledge instead of just acquire it”. (BLAIR, BRODEUR & YOUNG, 2002). According to Zhang (2002), PBL develops students’ skills towards teamwork and problem resolution, abilities sought by employers and often missed in lecture-centered methods. Even though PBL has completed 40 years of existence and validation, it is clearly a very recent approach, if compared to how long the traditional lecture-centered method of teaching has been under use.

Due to this fact, its literature is still scarce and it is frequently confused with similar methods such as "Project Work” and “Project-Based Learning”, which are however strongly related to PBL (KOLMOS, 1996). May it be clear that the acronym PBL in this paper refers strictly to problem-based learning. According to that author and to Delisle (1997), PBL brings up main features, as following the examples given:

a) Integration of disciplines and skills;
b) To help students to develop abilities to extend knowledge for dealing with real problems concerning to ethics, technical concepts and solving strategies;
c) To build a curriculum structured with thematic blocks;
d) To learn in small work-groups;
e) To foment self-directed learning for solving problems out of classrooms.

The structure of PBL requires realism at the learning process; therefore it involves multiple disciplines assembled into one subject. This fact changes curriculum significantly, as the process occurs in thematic blocks instead of the known defined courses. This ensemble helps students notice the relationship that exists between disciplines, whereas traditional teaching may present disciplines as separate subjects, and this fact will possibly cause harmful consequences. “The students in this learning situation are passive recipients. They may or may not learn the facts in a way that is useful in actual practice or work situations” (UDEN & BEAUMONT, 2006).

One of the basic components of problem-based learning is the ill-defined problem, which concerns realistic multidisciplinary problems, with unknown solutions or no unique optimal solution (CHIA & CHIN, 2005). “The scenarios enable students to become independent inquirers and help them to see learning and knowledge as flexible entities” (SAVIN-BADEN & WILKIE). Students must define the problem from a range of possibilities, work out a plan based on the type of problem and find one possible solution to apply and solve it. These core choices made by the students are the type of decisions real-life problems demand.
For comparison sake, it is interesting to consider the example of learning how to build an engine: problem-based learning corresponds to learning from taking a fully functional engine into pieces, while lecture-based corresponds to learning the function of each separate piece and assembling it from scratch. The main objective of the use of real problems is to stimulate students meanwhile they are acquiring knowledge by themselves, although supported by the teacher (BLAIR, BRODEUR & YOUNG, 2002).

PBL is a more rewarding teaching method for the students as they can notice their accomplishment. Then, well-defined problems generally have a single pathway in a single discipline, and are more of an exercise than a problem. They tend to be repetitive and provide shallow understanding of the subject. “Instead of assigning specific homework tasks, the teacher may want to develop a schedule for when each stage of the PBL activity should be complete so students can evaluate their progress and decide if they need to find additional time on their own to finish” (DELISLE, 1997). One other important fact to emphasize is that these problems must be presented at the beginning of the courses (CHIA & CHIN, 2005). In other words, an engine construction class may be turned out simpler, if students are presented to an operating machine online before they start studying each piece separately. Therefore, the basic principle of this approach is that before studying the theory, it is necessary to experience the real situation in which it will be applied.

2.1 PBL’s Characteristics

The most noticeable difference between PBL and the traditional method concerning to student involvement is that whilst regular teaching is lecture-centered, PBL is essentially student-centered (KOLMOS, 1996). That means that the learning process will emphasize how students’ acquire knowledge and skills rather than how lectures are made.

Problem-based learning was developed to increase the results of teamwork, so it stimulates and exercises activities of analysis in groups, presenting solutions and decision-making, characteristics that are widely demanded by employers nowadays (MILLS & TREAGUST, 2003). The groups are formed varying from 5 to 7 students, generally with a tutor for guidance. The professor and/or tutors have a much more difficult assignment inside the PBL method: from simple lectures and solving doubts, they must then elaborate problems that give poor information, but still doesn’t allow the students to rove through different areas which don’t belong to the subject. Teachers in PBL are metacognitive coaches (CHIA & CHIN, 2005). Teachers help the students to know what they are learning. “He or she must keep the discussion focused on the problem, help students to avoid conflict, give time for students to think, and allow time to answer questions” (UDEN & BEAUMONT, 2006).

It is a rather delicate job, as teachers cannot point the direction or tell groups exactly what to do, because this would take the core choices away from students (self-directed learning would be absent), and the problem would be similar to regular exercises. However, teachers can’t afford the time lost by studying other subjects that don’t concern the main problem objective.

Although PBL presents such amazing features and results, to make it a successful experience for learners it is required much dedication from both students and teacher. For that reason, PBL is considered for many referenced authors as an approach much more difficult to be applied than regular lecture classes. The next board shows arguments of three experts on difficulties that could be found during PBL implementation.

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<th>Author</th>
<th>Challenges of PBL Implementation</th>
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Due to these setbacks, the most common situation is to apply PBL on individual disciplines. Therefore the multidisciplinary constraint can be solved by linking the ill-defined problems to disciplines previously taken by the students, in spite of remaking the curriculum structure. For PBL application at Costs Management curriculum, it is possible to create direct links to Accounting and Finances, but also it is possible to integrate disciplines which were studied much longer before; e.g. Process Mapping; Production Planning and Control and yet Logistics.

PBL has thrived mostly in medical courses disciplines, where practice is highly demanded. But that is a widely recommended practice for engineering education as well, because the aim of this type of course is to form professionals and researchers who are capable to solve problems (and to find solutions through teamwork). However, it’s important to remark that medicine knowledge is mostly organized in a structure that missing one subject usually not affects the understanding of other (the study of different diseases symptoms, for example), whilst mathematics and physics are organized under a hierarchical and sequential manner where missing a subject is strongly harmful to the absorption and learning of technical knowledge (MILLS & TREAGUST, 2003).

This means that in the medicine disciplines, students are able to learn in a more free way: if they miss a topic, they may look it up again another time, while in engineering that flexibility is generally unlikely to happen. Thus, if PBL permits the students to skip important topics in such hierarchic-arranged disciplines, it will probably cause difficulties in further disciplines if the subject concerns to Engineering.

As a solution to traditionally structured courses similar to engineering, Kolmos (1996) has presented an interesting format, which consists on associating PBL to the ideas of a project work. Project work is defined as “a way of organizing the learning process”, as students must develop their work in a more active learning method than traditional teaching, and report it in a written report. The practice of the project changes the perspective of the students from observers to active learners who search and acquire knowledge. Kolmos (1996) proposes that there may be three types of project work.

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<th>Types of Project Work</th>
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<td>Assignment project</td>
<td>It provides a major control to the teacher, for it determines both problem and subject. Its objectives and methods are well-defined and constitute a simpler way of teaching and guiding the learning process.</td>
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<tr>
<td>Subject project</td>
<td>It brings about only the subject predetermined. Students may choose one method from a definite array, with the problem given, or they may choose to solve a problem within the given subject. The objectives have a wider range, because students have more choices, but the problems are still limited.</td>
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Problem project

It comes in activities with neither problem nor subject defined. Though there are some limitations, they allow a greater freedom of choice in this model, which grants the existence of multiple disciplines and multiple solutions. Students must decide their own pathway, what develops their methodical skills.

Source: Adapted from Kolmos (1996)

Analyzing the three models, it’s easy to notice that PBL is barely present in the first, partially present in the second, and mostly present in the third. The author states that these three types are all necessary for disciplines, for there are ones that require a more technical or a more methodical approach, and depending on the focus of the institution or the courses, these types may be applied throughout the years, so students may learn the human relations and methodical skills they need without compromising technical competence.

Traditional courses as engineering have scenarios that seem to agree more with familiar ideas like project-work than with new ideas from new methods like problem-based learning (MILLS & TREAGUST, 2003). Regarding this fact, the application of partial aspects of PBL, or its association with more traditional methods seems to be the most logical way to introduce problem-based learning in regular engineering courses.

Additionally, according to UDEN & BEAUMONT (2006) this method relies on three basic principles:

a) Activation of prior learning via problems;
b) Encoding specificity;
c) Elaboration of Knowledge via discussion and reflection on consolidated learning experiences. Therefore, converging to the statement above, it is relevant to stand the steps of PBL process, which were established by Camp (1996).

The PBL Process

Problem

The problem is first encountered in the learning sequence before any preparation or study has occurred. During this part of the PBL process the learning issues and the problem to be solved is presented to the student in the same way as in real life. In this phase, the terminology is presented and some previous concepts are required from students in order to start the next step.

Ideas (brainstorming)

The professor proposes a discussion about which are the tools that might be used to solve the presented problem. The student works with the problem that allows him/her to reason and apply knowledge to be challenged and evaluated as appropriate to his/her level of learning.

Knowledge

The next step is to structure the knowledge coming from the brainstorm, where notes must be taken and the tools must have been already selected. These are used as a guide to individual study.
Learning Issues Skills and knowledge learned by this study are applied to the original problem to evaluate the effectiveness of learning and to reinforce learning. That is the appropriate moment for students star to solve the problem presented in the beginning of the process.

Course of Action Possible solutions for the problem must be presented and discussed with the class after simulation tests or after the evaluation of scenarios. The learning that has occurred in working with the problem and in individualized study is summarized and integrated into the student’s existing knowledge and skills.

Source: Adapted from Camp (1996) and Reno (2010)

Board 3 – The PBL Process

Once they are presented the concepts and steps to apply the PBL approach, in the next sections there will be presented the methodology bases on which relies the construction of the case; as well as the results obtained during this study.

3. Methodology and Tools

As mentioned before, this work consists on the realization of an investigation process aiming to explore and to analyze university students’ adherence into the PBL approach at the discipline Costs Management. As the students had previous failure in this discipline, when the traditional method was applied, the class presented a unique potential for taking part of a further study: the elaboration of a comparative Survey between the PBL and the theoretical expositive class methods.

Survey is a methodology widely used on rather social or marketing descriptive researches that have as object to observe and analyze opinions, preferences, perceptions and behavior of a determinate population. In order words, according to Miguel et al (2009), such type of methodology helps researchers to understand in quantitative terms the perception of human groups about a certain subject.

The activities of research were developed in classroom during three months with two sessions per week and with students who voluntary accept to be part of this experiment. The tools utilized to perform this work were:

a) Forums to present the PBL approach and the use of real industrial problems concerning to Costs management and Operational Research;

b) Structured Interview with 4 of the 5 students who were taking the discipline;

c) Formulary composed by rather multiple choices questions and discursive questions

The multiple choice questions concerned to measure attributes of the students experiences at PBL classes and Expositive classes approaches. The formulary proposed by the researchers to invite the students to declare through a semantic scale their perception of the main learning issues worked in classroom – and how the class has adapted to PBL. The scale proposed an evaluation based on the definition of grades between one and five. The items composing the formulary were related to the teacher’s role, their experience while they were responsible for every taken decision during the case studies, impacts on self-confidence during the course, etc. The discursive part of the formulary was used to acquire extra information about the students’ perception of the environment. The commented results of this research are presented in the following section.

4. Results and Discussion

The Costs Management discipline is usually taught in the fourth year of the Production Engineering course at UEPa. The subject course duration is 60 hours per semester when the
class is congregated twice a week for studying topics related to finances for industrial control of Supplies, decision considering restrictions of production capacity and analysis of profitability through various Costs Management models.

The original teaching strategy to run this subject was to divide the course into two different parts:

a) The first moment was the ministration of concepts and traditional expositive classes;
b) The second period counted with the use of MS Excel to solve theoretical exercises.

Although the discipline was performed on conceptual basis only, without using real problems to support learning, the study of Costs Management at Production Engineering required previous knowledge as the following topics: Logistics, Supply Management, Operational Research to support decision at finances, Operational Management and Business Management.

As the annual failure taxes are considered high (usually 22.8%, with small variation on previous years) – Oliveira (2009), it is common to find special groups of repeaters who are coursing Costs Management for a second or third time, although they have reached the fifth year at UEPA.

Initially, 48 students at ages between 20 and 30 years old composed the original group, which was studied during the elaboration of this work in 2009. At the end of semester, 9 students had not accomplished success on studying Costs Management, then, in the beginning of the next year they were supposed to take the discipline again. From this second group, only five students have made their application to take the discipline in 2010 – (OLIVEIRA 2010). The other four students, however, decided to wait one more year before trying Costs Management again. In result of this context, only five students have taken part of the implementation of the PBL approach. Then, the results presented in the next section are related to the students who volunteered to be part of this case.

The aim of this research was to measure through a survey the perception of these students about their own learning after a drastic change in the teaching method of this discipline, by the comparison of the advantages and disadvantages of both teaching strategies.

4.1 Undertaken Cases

The first step of the PBL process is presenting to the group which problems are being set to be solved during the semester. In order to initiate that stage, at the inaugural class the reunited group attended to a lecture of sensitization. The first day was critical to present to the class the different issues which were included into that discipline. The subject summary was presented concatenated with two other documents:

a) The semester schedule;
b) The real problems menu, which would be solved during the course.

For example, the first problem was presented as a case study which aimed to lead the students to find out the Brazilian accounting legislation and the main Management Cost Tools. The context called the reality of a real small beverage factory that experienced an evolution at its management structure, by the acquisition of a Management Information System which required the Industrial Manager to decide which Costs System should be the most appropriate to the company’s reality.
Three weeks after the first contact with the case, students were programming a test spreadsheet integrated to the factory’s database in order to calculate all the direct and indirect costs consumed in April, May and June of the past year. Once this step was concluded with the validation of the spreadsheet, students were invited to build another system to calculate the unitary costs of the four main products of the company. At the end of the weekly activities, small forums were performed with the professor monitoring the group development. One similar process was lead at the study of the second problem.

Immersed in this environment, the perception research was applied on the group in order to measure their perception meanwhile they were experienced the PBL method. Then, in the next section, the results obtained are presented.

### 4.2 Results Obtained

The questionnaire proposed 18 questions concerning each method and also presented four open-ended questions, in other to provide a wider comprehension of students’ perceptions. The group has graded the closed-ended questions at a scale with a gradient set from a minimum of one and a maximum of five, where all grades should be an integer number. For the learning issues and the discipline issues, the averages of grades were reckoned for each method and compared through a horizontal bars graph. At the professor issues, the same reckoning was taken and a radar graph was made for the eight aspects.

At picture 1, it is possible to observe a sensible increase during the measure of student’s interest on the subject. That is as positive mark because that issue is closely related to the group motivation.

Surprisingly, during the comparison, the group has evaluated negatively the item “group work influence” while analyzing the PBL. Through the qualitative part of the questionnaire, it was possible to identify that, during the sessions of group work, part of the students was uncomfortable with sharing the responsibility of taking decisions while immersed into a real context. Then, the grades attributed to this issue have ratified a decrease, if compared to the traditional expositive class method.

The answers related to the question about material comprehension have pointed an evolution with the use of PBL. This may have potentially occurred because, during the content presentation, the applications of Management Costs were contextualized into one real case concerning a Production System located at the State of Para.

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<th>Learning Issues</th>
<th>PBL method</th>
<th>Traditional method</th>
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1. Student interest;
2. Student comfort;
3. Problem relevance;
4. Group Work influence;
5. Material comprehension.

Picture 1 – Learning issues under PBL versus Traditional method
The general results obtained by this evaluation of learning issues demonstrated a positive growing tendency at students perception during the use of PBL. However, part of the group has declared their lack of self-confidence with the new learning approach. That statement might be sustained by the perception results acquired throughout the applied measure of professor’s issues questions.

An overall look clearly shows PBL has some advantage over the traditional method, especially on student interest.

![Professor Issues](image)

In professor issues, PBL was overtaken by the traditional method. Despite the latter loses by a large margin in accordance between content and market’s objective, it wins in methodology adequacy, the settling of theory and practice in the discipline, stimulation and coordination of group work and clear explanation. The remainders present no difference whatsoever.

As the tutor plays a significant role in PBL, its evaluation is indispensable. Aspect number one of professor issues, as well as aspects number six and seven, present the same grade, as it was supposed to, due to the fact that they estimate features somewhat similar, even in different learning methods: content understanding, fair evaluations and accordance between content and objectives. Acknowledging that these issues assess mostly the teacher, and the high grades obtained, it is reasonable to state the professor proved to be capable both as a lecturer as a tutor.

Regarding aspects number two and five, methodology adequacy and settling of theory and practice, respectively, the regular method won over PBL. These are important issues, as the methods differ greatly in methodology and application. In the open-ended questions, students complained about how the tutor in PBL lacks in providing theory, although, praising the real-life practical exercises. Therefore, it is important to judge if such low grade to problem-based learning is not biased by the fact that students were used to the lecturer teacher, rather than the guidance-providing teacher, as the former is a lot simpler to the ones who did not develop a proactive discipline to seek for the knowledge. It can be remarked the same for issue number five, as students may comprehend that, if they do not receive the content from the professor, the content explanation has been compromised.
The largest margin in the graphic is in accordance between content and market’s objectives, issue number eight. PBL won with visible difference, for students noticed how the real life problems align better with the market’s objective, rather than the regular exercises proposed by lecture-centered teaching method. While exercises may allow a more solid comprehension, problem-based learning’s ill-defined problems provide the opportunity to make decisions and choose paths, going beyond the understanding of a subject: the utilisation of this solid understanding to problem-solving.

Finally, at the section discipline issues, the opinions in classroom were straightly pro the PBL, as every researched item has achieved a higher perception grade than the traditional class method. For example, results about knowledge utility, which during this research was declared as one of the most important issues for the senior students, has shown an evident increase.

![Discipline Issues](image)

In general, although students have shown some resistance during the first contact with PBL, in part because some members of the group would not be willing to change their role from a knowledge receiver into a constructor of knowledge, based on the commented results it is valid to point this experience was a successful application of PBL on Engineering Education.

5. Conclusions

This work proposed to present a survey concerning to senior students’ perception of their learning in the discipline Costs Management of a graduation course of Production Engineering at Brazilian Amazon. The class studied has taken part of this research voluntarily after the group had failure on their regular course in 2009. The application of the formularies and a complementary interview were successfully performed with 80% of the class and the results were optimistic in the year 2010. As one positive result from this research, it to notice the difference obtained at the students learning comfort by the establishment of the use of real problems into the classroom environment.

Even though PBL is clearly a more time consuming path, students surprisingly stated it is more effective than the traditional method, giving the course duration. This may represent that PBL’s exercises and practical approaches may be more straightforward, and therefore, more effective in the learning process, as measured by the learning issue number five (material comprehension), and discipline issues of numbers three to five (material sequence, quality and utilisation), where PBL got a higher grade.
Group work influence (item number 4 in learning issues) and stimulation and coordination of group work (item number 4 in professor issues) have experienced an interesting fact: PBL nurtures group work, but the traditional method got higher grades. The explanation was found in the questionnaire’s open-ended questions, as a student said that one of PBL negative aspects was that students wouldn’t gather to study outside of the classroom, and another student would mention the greatest obstacle in PBL learning as being the development of a self-discipline. This brings up the lack of self-directed learning, which is potentially the main problem expected to rise in this experience.

Self-directed learning is a vital piece to success in problem-based learning. As long as students will not bother taking action, to acquire knowledge by themselves, PBL won’t thrive. One student claimed that a negative point of PBL was the lack of theory, and as a positive point of the traditional method, the fact that the teacher presents most of the content. This opinion clearly shows how students feel comfortable when they play the role of recipients, and the teacher, the one who must fill these recipients with knowledge. And as a recipient, the student denies the task to learn by himself, the ability to make decisions and how to evaluate the best solutions. Then, all the principles the PBL method and main corporations stand against.

PBL can be considered as an established approach at the medical sciences at various universities and countries, however it is not possible yet to stand that its use on Brazilian Industrial Studies are widely consolidated. Finally, although, the experience at University of the State of Para (UEPA) with failure students was a positive mark while an innovative effort to increase the quality of education of one specific area of Production Engineering, it cannot be discarded the possibility of application of the PBL on disciplines with higher indexes of approbation or on those subjects which require a deeper theoretical background of quantitative knowledge.

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