Using Cognitive Maps to Support the Problem-Based Learning Evaluation

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ABASTRACT

This work aims at to search the learning performance of the Civil Engineering students using the Problem-based leaning (PBL) method as part of pedagogical innovations in Engineering Transportation course. A questionnaire for the assessment of learning was built to analyze the performance of the sample and the PBL effects resulted. The questionnaire built contributed to evaluate and compare the learning of the sample with a group of students submitted to the conventional class design. Cognitive maps were used as a strategy to investigate the instructional innovations, specially the PBL effects and the existence of distinct learning performance among students. The results indicated that PBL students were engaged in their own learning and performance. Furthermore, they reached stronger behavior development, attitude, and involvement. They demonstrated increased satisfaction and a significant learning performance with the new pedagogical innovations in the design course. Finally, some research suggestions are also proposed.

Keywords: Problem-based learning, Cognitive maps, Engineering education.

1. INTRODUCTION

Adjusting the teaching and learning engineering to the innovations and decisions established by profession of the future engineers has been a challenge to the engineering schools all over the world. Professors, researchers and experts from many higher education institutions, as the ones from the engineering education [1] - [5], who have found to adjust or restructure the curriculum to improve the engineering courses to promote better engineers professional practices.

In Brazil, some professors and researchers [6] - [8] have also found instructional alternatives to provide improvements to the teaching and learning process in engineering. One of the pedagogical innovations implemented in one course in Civil Engineering is related to the use of the Problem-Based Learning (PBL) in a distance education platform, based on students' learning preferences [7] and [9]. The use of this pedagogical alternative, associated to the course content, composes the starting point for the accomplishment of part of this study.

By understanding that the adoption of instructional alternatives can improve the teaching-learning process; the proposal of the current work is the investigation of the students' performance in this pedagogical experience, mainly referring to the use of the PBL, as a learning method, in Engineering. To evaluate the efficiency of the instructional proposal in the students' performance, especially the PBL method in the students' improvement, it was used an innovative structure which strongly contributed to the investigation. The challenge was to perform the learning evaluation based on problems using the technique of the Strategic Options Development and Analysis (SODA) in the construction of cognitive maps.

The use of mapping to evaluate the learning allowed a deeper investigation of the students' performance, as well as PBL method effects on problem-based learning evaluation. However, there are no studies which integrate cognitive maps on learning evaluation using PBL as method in engineering education.

2. PROBLEM-BASED LEARNING

PBL was constituted as a method in the beginning of the 1970s, with Barrows and Tamblyn's studies [10] – [12]. PBL was developed to supply the difficulties found in teaching in medicine course [13] and [14]. According to [15], the students concluded the course with many concepts, but few behaviors and strategies associated with the information applied to a diagnosis.

The "ideal" learning method include the acquisition of knowledge, high self-esteem, critical thinking, problem solving skills, and life-long learning, providing better professional practices and personal development. In this sense, PBL learning provides learners attributes, according to [16] increasing higher-order thinking skills, explore authentic and ill-structured problems, and the possibility to students take part in social interactions and receive coaching from peers and teachers.

As [17] note, in PBL the learning objectives and activities are based on the knowledge and skills needed to address problems encountered in the field. Thus, PBL emphasizes learning instead of instruction, in contrast to traditional methods. Since problems do not respect the disciplinary boundaries, PBL often involves collaboration and integration of a wide range of disciplines or subjects. This requires knowledge interaction from several issues and courses. This experience intensifies the ways to conduct, grasp or learn how to learn, before its complete application [18].

PBL is generally applied approach of learning in areas related to health and as a general model initially was developed for medicine teaching, but PBL has been refined and implemented in several schools [19]. PBL has been adopted in areas including administration, nursery [20], pedagogy [21], [22], engineering, architecture, law, social service [23] and, even in other levels of education, such as primary and high school [24], [25]. Moreover, in the twentieth century, it was extended to countries such as Australia, Holland, New Zealand and, today many universities and schools have their programs developed from PBL.

In Brazil there are few universities and courses which have adopted PBL, as reported by [15], besides the medicine course initiated at the Federal University of São Carlos in 2007, which uses PBL as a teaching-learning method. However, these initiatives are still scarce, showing the need of researches involving PBL in Brazilian education, though is possible to verify significant results where PBL has been implemented. Since, PBL is an adjustable method for a variety of educational environments [24].

Many researches have shown the efficiency in PBL learning performance improvements. According to [4] and [5] PBL is recommended in engineering, particularly because it provides a deep learning and develops problem solving skills. In addition, PBL supplies significant improvements to the development of general skills and positive attitudes [4].

However, experiences carried out using PBL point to the necessity of changing in habit of both students and teachers to deal with the active learning strategies and independent learning. According to [3], some students find it difficult to become active critical thinkers and, some professors may face difficulty when performing their role as tutors, managing group work or, even challenging students to develop critical thinking.

Conversely, [8] points to the advantages in PBL method adoption related to the students' grades. By using a quantitative approach was possible to prove the development of higher levels of performance using PBL. Theses outcomes can be observed in Table 1.

Table 1. Test average between PBL and "Traditional" students

Methods	Students	Mean	Standard Error	Standard Deviation	[Confidence Interval - 95%]	
PBL	29	6.568	0.1866	1.005	6.186	6.951
Traditional	26	5.2	0.3054	1.557	4.570	5.829
Set	55	5.921	0.1964	1.457	5.5279	6.315
Difference	—	1.3689	0.3498	—	0.6672	2.0707
diff = mean(0) - mean(1)					t = -3.9127	
Ho: diff = 0				degrees of freedom =	53	
Ha: diff < 0		Ha: diff != 0			Ha: diff > 0	
Pr(T < t) = 0.0001		Pr(|T| > |t|) = 0.0003			Pr(T > t) = 0.9999	

The result, considered statistically significant, indicates that the students who learned through PBL obtained an addition of 1.368 on average when compared to the students who learned through traditional method. This lesser variability points to the fact that PBL reduces the heterogeneity in students' grades. Previous outcomes involving students' grades and their performance can be found in [8].

3. METHODOLOGY

This study involved 30 undergraduate students of a Civil Engineering course in São Carlos School of Engineering, at the University of São Paulo. The Planning and Analysis of Transportation System course is a subject offered to Civil Engineering course which the sample are representative of two classrooms. This subject is usually taught by two professors, each one responsible for one classroom. The students are separate in two groups: (group 1) - 12 students who experienced PBL as part of the new pedagogical proposed by one of the professors in the subject, experience described in details by [7] and [8]; (group 2) – 18 students who attended the subject with "traditional" teaching methods, by another professor.

To investigate if the adoption of PBL resulted in a better students' performance, a questionnaire for learning assessment (QLA) was applied to the students. QLA was made by the professor responsible for the new pedagogical proposal. QLA is comprised of two parts. Part 1 is divided into three topics (Questions 1a, b and c), concerning the planning and analysis of transportation system theory. Part 2 proposes two problems (Questions 2a and b), involving practical application of knowledge and techniques developed in the subject.

Part 1) What do you mean by:

a. *Planning of Transport Systems*;
b. **Analysis of Transport Systems**;
c. TRANSPORTATION SYSTEMS.

Part 2) You´ve just got applied, along with fifty candidates, to the last stage of a selection process to compete for a place of engineer in a large company that operates in the field of Logistics, located in Campinas, São Paulo. This step is decisive for the choice of professional to be hired and will be based on the assessment of the alternatives you submit to the following two problems:

a) There is a demand located in Milagres, Bahia, for a particular product, which is produced only in Campinas and is valid for 24 hours. Knowing that should be given regular doses of medicine in the next 15 days, with delivery of a box of 5kg per day, how would you transport this product and how could you think of the cost transportation to the buyer?

b) The company intends to apply for a bid that provides for the delivery of the entire supply of alcohol fuel needed to meet the city of Manaus in the next 5 years. Which alternatives and costs can you think the company must submit to compete for that contract, knowing that alcohol is available in Paulínia, São Paulo?

Chart 1. Questionnaire for learning assessment

QLA Part 1 was structured in a way that the students could show their understanding in relation to the three topics, and their responses allowed to collect the central concepts dealt with in the discipline. In Part 2, the problems a and b were proposed allowing students explore the techniques and the intrinsic knowledge to the subject.

Students' responses allowed the construction of cognitive maps using the Strategic and Options Development Analysis (SODA) to group several maps, making possible a better organization and view of the data in them. The technique employed and the constructions of those maps are founded in [26] and [27] about cognitive maps.

Among several possibilities of use, the cognitive mapping can be seen as an attempt to isolate and represent the individuals` constructs and their hierarchical use. This way, a map can be seen as a network of ideas, which can be captured directly from someone who expresses them, and they are connected so that reflecting the way as, in this individual's perspective, they relate to one another.

In this study the maps represent briefly the students' understandings and perceptions about the topics of the subject. The aim was to investigate the use of PBL in the students' performance, by comparing the responses supplied by the participants, as well as the non-participants of the experience.

The concepts presented in the maps express the understanding, explanations, strategies and data used by the students, whereas the link between the concepts are represented by arrows, which indicates how a concept leads to, or has implications upon the other one. Knowing that the concepts generally reflect the understanding of the student about the questions, the maps are designed in a way that they flow from the center to the border.

In order to organize the responses on the maps, mainly in Part 1 of the QLA, was adopted a system thus, in Part 1 Question 1a is in italics (*Planning*); Question 1b is in bold (**Analysis**); Question 1c is in upper cases (TRANSPORT SYSTEM). Furthermore, there are cases in which the concepts involve Questions 1a, 1b and 1c, being represented simultaneously by the three resources aforementioned. To Part 2, the responses to Question 2a are located in the upper part of the figure, whereas the ones related to Question 2b are in its lower part. The results of the cognitive maps are analyzed and discussed in the sequence.

4. RESULTS: COGNITIVE MAPS AND THE STUDENTS' PERFORMANCE

The results of the use of mapping as a way to investigate the students' performance in adoption of PBL and its effects as part of a pedagogical innovation provided evidence that alternative instructions can favor the teaching and learning process, especially in engineering.

Regarding fist mapping, Figure 1 shows the students' understanding about topics 1a, 1b and 1c of the QLA Part 1. The map represents briefly the responses of group 1 at the top of the Figure 1 and group 2 at the bottom. The detailed maps can be seen in [8].

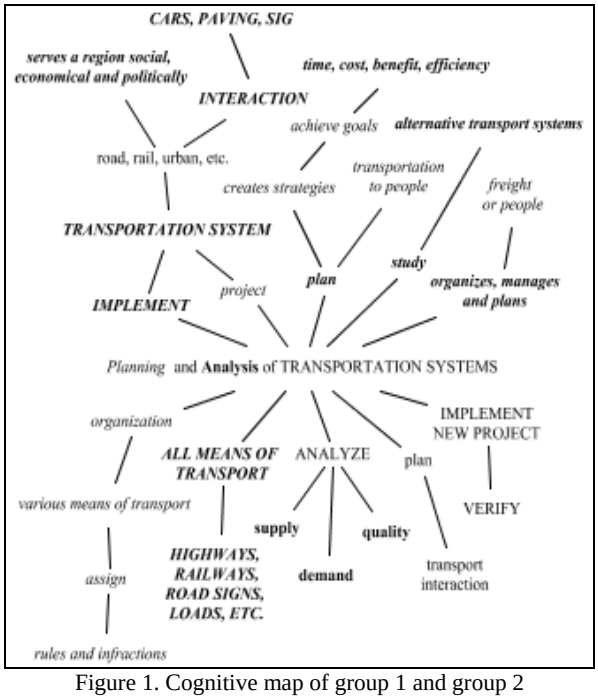

Figure 1. Cognitive map of group 1 and group 2

In general, through the responses on the maps is noted that group 1 grasp the most general subject concepts, pointing out their meanings, functions, purposes and examples of use referring to planning, analysis and transportation systems. It can also be noted that the range and depth level in the way the questions were answered, pointed by [28] as fundamental in

problem solving. This suggests that PBL fostered a positive effect considering the way found by students to solve the problems.

Although, there were no strong differences between responses compared to group 2. It is possible to note that through the conventional teaching method group 2 showed the development of memory techniques related to this method, allowing this group answered the questions, even without the concepts make sense to them.

Moreover, solving questions Part 1 and 2 indicates the development of techniques related to PBL understood during the experience that involved the use of the method by group 1. Such ways demonstrate that group 1 became progressively responsible for their own learning, facing the fact that they took the responsibility over the selection of the information in the field to be explored, and deciding on the level and amount of information to be used. Furthermore, this result shows greater skill and, especially, maturity in dealing with the problems, indicating greater commitment with their own learning.

Another result is related to the impact the PBL could cause on group 1, owing to the time they were exposed to the conventional teaching environment, thus affecting negatively their performance until they could develop new study habits, as pointed by [29] and [1]. Nonetheless, this impact was not verified in this research, on the contrary, the students involved with the instructional alternatives showed that, even with the use of the PBL method, they obtained good performance, and, in general, they also showed more interest to learn.

On the other hand, when referring to the practical application of the proposed problems, questions 2a and 2b, it is possible to notice significant differences between students who participated in the new pedagogical proposal and the ones who did not, as presented in Figures 2 by group 1 and Figure 3 by group 2.

Figure 2 shows a greater number of details with the use of procedures, suggestions, ideas and estimation, which generally suggests significant performance of group 1; keeping in mind the range and depth level of the responses. We also can observe that, at least, for the questions involving practical application, group 1 showed effective apprehension of the concepts worked at the subject, as it was perceived through the options and possibilities indicated. In addition, such as viable means of transport, offer and demand costs of the products that make part of the problems pointed, better routes, via land, air or water, problems for better ways of transportation, deficiencies, possible places to arrival and departure, expenses, etc.

Students also using the internet, searching previously information, such as transportation costs and services offered, distance between places, route indication based on road maps. Besides, the students took the initiative to get in touch by e-mailing to companies specializing in freight, to make possible the practical use of previously learned concepts and techniques. The ways that students adopted to solve the problems clearly reflect PBL method characteristics. This statement indicates the development of certain skills related to the method, because it is possible to realize expressive autonomy at the problem-solving process.

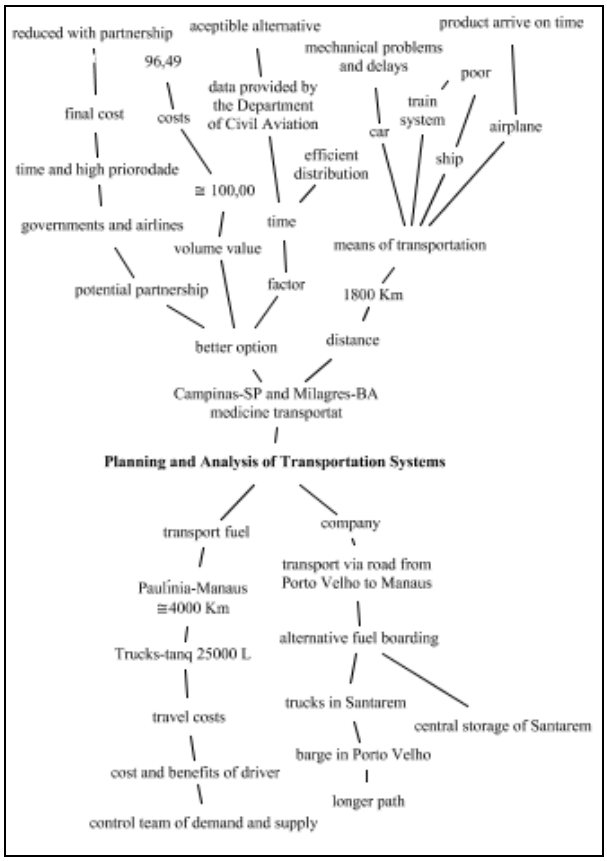

Figure 2. Cognitive map of the responses Part 2 - PBL

Students identified key issues, focused their efforts, and indicated the resources. As they applied their knowledge, they discovered and explained them for their classmates, thus developing new cognitive and social skills, responsibilities and comprehension, that is, they have leaned by doing, according to [30], about the students' learning and the PBL method characteristics.

The comparison between the maps constructed by group 1 responses showed in Figure 2 with the ones by group 2 showed in Figure 3, reveals that, although both groups find to attempt solving the problems, the responses of group 1 indicated the use of the knowledge and techniques worked within the experience, mainly the use of PBL method.

Certain differences can be noted, not only by the way the questions were answered, that is, the techniques used, but also by the solutions found, which were demonstrated as viable ones for the proposed problems, either generally or relating specifically to part 2 of the QLA.

As we have seen, although the students were exposed to the experience for a short period of time, only one semester, the new instructional design promoted greater levels of performance and the development of desirable behaviors and attitudes for the future professionals, showing the viability to implement PBL as a method in engineering education, in general.

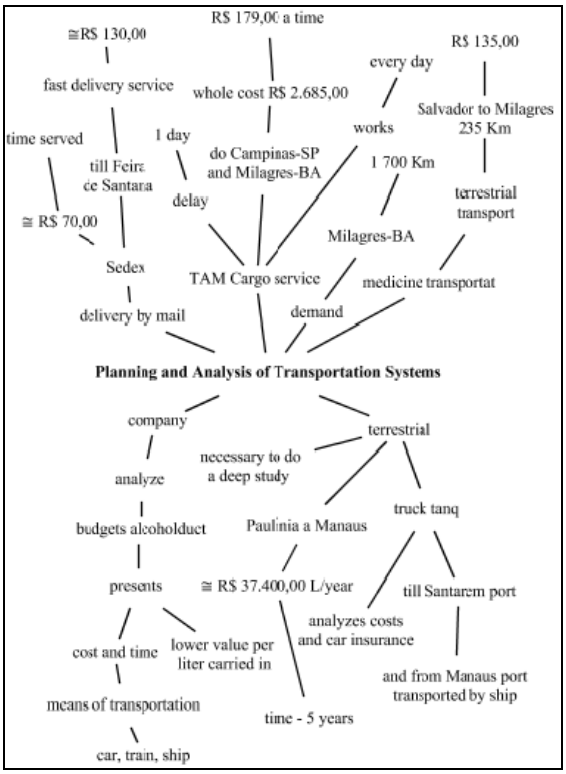

Figure 3. Cognitive map of the responses Part 2 – "Traditional"

5. CONCLUSIONS AND FINAL CONSIDERATIONS

This study aimed at investigating the effects of the PBL method among students who participated of the pedagogical experience, comparing their development to students who did not take part on the innovative experiences. In face of the results of QLA applied to both groups, the results showed significant effects at the students' learning, who taught through PBL.

The positive effects of the PBL method were related to the development of problem-solving techniques and point to students` commitment and responsibility considered to the learning, in order to suggest the development of a more fully understand. In this way, this finds shows a significant difference between PBL and traditional method. Even though the second method allows the accomplishment to the task of solving problem that, in general, it was only this, without the commitment with the learning, disfavoring the development of critical and creative thinking and interest with the own learning.

According to [18], as the PBL convergence point influences the students, they become constructors of their own knowledge. As a result, the fact that the PBL students showed commitment with their own learning demonstrates the development of differentiated behaviors and attitudes, favorable to the PBL students. PBL has shown as a viable method for education in engineering.

Furthermore, the implementation did not cause a negative impact in students' performance, as they were receptive and involved with teaching-learning differentiated methods and pedagogical innovations in the instructional environment, such as the ones demonstrated here and previously proved in studies as in [6] - [9].

Finally, this study suggests that the adoption of other methods and pedagogical alternatives to the education in engineering can provide teaching-learning processes more suitable to the professional profile that today's society needs, since conducted and evaluated with proper techniques and instruments.

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