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Implementing a Data Network Infrastructure Course using a Problem-based Learning Methodology

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ABSTRACT

Education professionals are always searching for new ways of promoting learning, either by modifying the pedagogical project of courses or by the adoption of new learning strategies. In particular, this paper presents the results of an effort in order to bridge the knowledge acquired by students within classroom in face-to-face classes with technical skills required in real life situations. The contribution presented in this paper is the result of an assignment applied within an undergraduate Data Network Infrastructure Design course in a Brazilian university using an adapted Problem-Based Learning methodology (PBL), as a motivational tool. This paper also presents and discusses the resulting data related to the learning assessment.

Keywords: learning assessment, problem-based learning, computer networks

INTRODUCTION

Currently the market requires cutting edge and skilled professionals, especially when it comes to Technology and Information domain. In order to fill this gap, one important approach is to provide a bridge between theoretical aspects discussed within courses with the technical skills applied in the daily routine of the professional world. It is important to note that students consider some TI courses, such as computers architectures, operating systems, distributed systems, computer networks, among others; as hard to understand only through a theoretical approach. Indeed, these courses are mostly based on tangible aspects which demand students to visualize and experience their software and hardware aspects. In the opposite, even though it is possible to carry out hands-on classes in laboratories, these classes are unable to expose students to real life situations they are supposed to face in the daily routine of the professional life. For this reason, there are always gaps to fill out left by the academic approach.

Even though new learning objects and resources are constantly proposed, such as simulators, gaming, emulators, among others; it is still hard to provide students with a complete technical perspective and practical knowledge required for problem solving in companies.

According to Correa and Martins (Correa and Martins, 2016), an approach for shortening the gap between theory and practice can be achieved through the application of Problem-Based Learning (PBL) techniques, once they are based on real problems and they provide students with the opportunity to propose a resolution strategy, which contributes to the full understanding of the problem and its solution. The application of PBL techniques allows students to develop skills such as teamwork, self-assessment, problem-solving, etc. (Klein and Guridi, 2010).

Some researches in the literature have presented the use of PBL for improving teaching and learning IT courses (Correa and Martins, 2016), (Nobre et al., 2006), (Bertoncello et al., 2008), (Ribeiro, 2008), (Rodrigues et al., 2015), (Helerea, 2005), (Alcázar and Fitzgerald, 2005). In this context, it was also possible to observe the difficulty students had to relate theory learned within classroom with laboratory experience in order to fill the gap of real cases scenarios within an undergraduate Network Infrastructure Design course in a Brazilian university. At the same time, an opportunity came up to apply the concepts studied in this course in a real environment through the implementation of a network infrastructure in a public high-school, with about 1500 users (among students, teachers and employees).

This paper aims at presenting the results of the implementation of this computer network infrastructure, through the application of PBL and its impact in the learning process regarding both the students who participated in the design of the infrastructure and the students who participated in the hands-on implementation of the network (Martins et al., 2017). The assessment of the learning impact using PBL is carried out through the comparison of the results of the students who followed the traditional learning methodology (face-to-face and laboratory classes) and those who carried out real implementation.

This paper is structured as follows: section "Problem-Based Learning (PBL)" presents the theoretical foundation about PBL; section "Related Works" discusses some related researches; section "Real Case: Network Infrastructure" introduces the description of the experiment, presenting PBL oriented issues; section "Results And Discussion" presents the learning evaluation results assessment, and; finally, section "Final Considerations" discusses some final considerations about the developed work and some future perspectives.

PROBLEM-BASED LEARNING (PBL)

The Problem-Based Learning (PBL) is an instructional methodology used by student to learn through problem-solving technique (Hung et al., 2008), (Lino et al., 2017). Dewey (Dewey, 1910) conceived this methodology in a "learn by doing" basis so that students use their ability to think, in a gradual way, during the acquisition of knowledge related real life problems.

This methodology has the following characteristics (Hung et al., 2008), (Savery, 2006):

- It is problem-oriented. The resolution of problems enables learning new context and skills. The construction of knowledge is provided by problem-solving and is applied back to problem-solving. There is no hierarchical list of topics such as in a conventional learning methodology;
- Students determine their pace of learning;
- It is self-directed. Therefore, students generate their own learning issues and processes, individually or collaboratively, through self and peer assessment;
- It is self-reflective. Therefore, students manage their understanding and are able to adjust their learning strategies;
- Tutors are only facilitators and never disseminators of knowledge.

Given the previous features, PBL methodology is not a process of passive reception and accumulation of information, but it is about active knowledge building. According to (Ribeiro, 2008), (Hung et al., 2008), (Araújo et al., 2009), (Campos, 2011), PBL is based on constructivist assumptions about learning, such as:

- Knowledge is not transmitted from professor to students. In the opposite, it is built individually and co-built in a social way, using interactions with the environment. Learning is enhanced through social interaction and is facilitated when students are exposed to real life situations.
- To understand every phenomenon, students need to have multiple perspectives related to this phenomenon.
- Knowledge is related to relevant contexts. In order for information to become knowledge it is necessary to activate existing cognitive concepts and structures on the subject matter, and to enable students to elaborate and assign new meanings.

RELATED WORKS

This methodology has been widely used since 1950s in the medical field for training students who were un satisfied with the traditional and inefficient ways of memorizing information (Hung et al., 2008), (Mills and Treagust, 2003). Since 1990s, PBL has been adapted for many educational contexts and teaching several areas of knowledge.

The application of PBL in teaching Exact Sciences has been well documented in the literature (Nobre et al., 2006), (Araújo et al., 2009), (Campos, 2011), (Helerea, 2005), (Alcázar and Fitzgerald, 2005) where it is sometimes

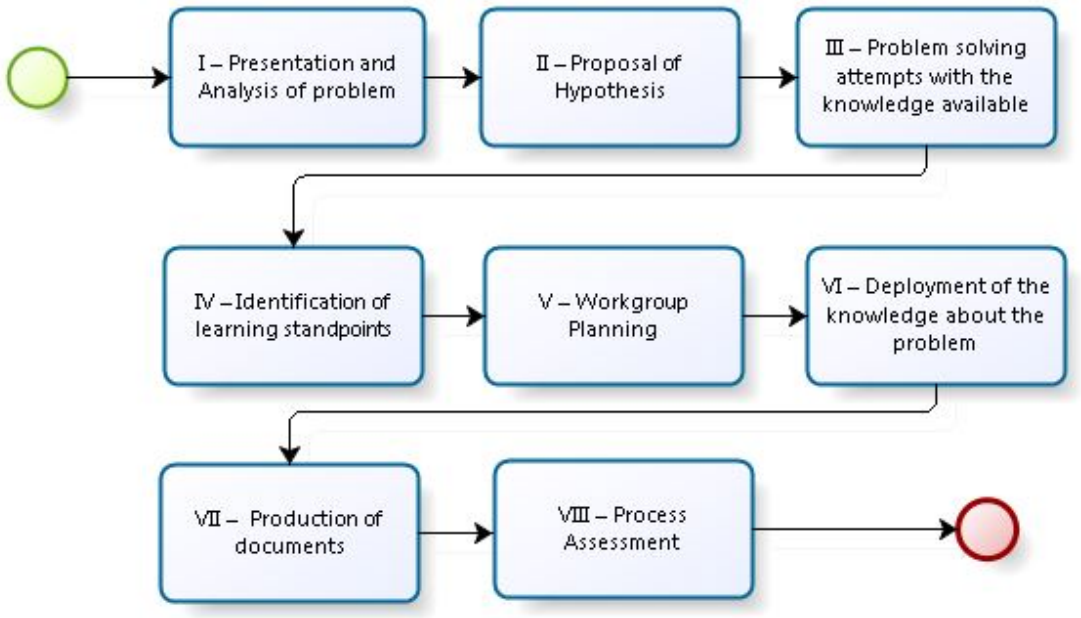

Figure 1. PBL methodology applied (adapted from (Ribeiro, 2008))

called "Project-Based Learning". The contribution introduced in (Campos, 2011) addresses the difference between problem-based learning and project-based learning for engineering teaching. Regularly, the hybrid PBL methodology - Problem-Based and Project-Based Learning – has been used in the Computer Science area applied to problems/projects and worked by groups of students and facilitated by tutors.

Currently, there are some contributions in the literature concerning the utilization of PBL methodology in different areas, considering either its practical application or its adaptation to a specific context. Correa and Martins (2016) applied PBL within a Human-Computer Interaction (HCI) course. In this work students had to carry out usability evaluation for the development of a web site aiming to teach research methodology in a free-access on-line course. The model was applied in three different IHC classes with 16 students and 82 users in a Brazilian University. In (Nobre et al., 2006) PBL is introduced in the development of a final assignment project regarding two different courses (i.e. Embedded Systems and Real-Time Systems) in the undergraduate and graduate program in Electric Engineering and Computing System at Airforce Technological Institute (ITA) – Brazil. Bertoncello et al. (2008) proposed the integration of Information and Communication Technologies (ICTs) with the PBL methodology. The authors applied a tool for data storage in order to help students to determine initial aspects of the solution for the problem proposed by the professor. These aspects were evaluated later on based on the stored data in order to track similarity indexes. Ribeiro (Ribeiro, 2008) presents some alternative formats and approaches for the original McMaster´s PBL technique. The author introduces a sequence of work cycles with problems. Some of these cycles were adapted in this current work. Rodrigues et al. (Rodrigues et al., 2015) present the development of a robotic platform for exploration environments, derived from the use of PBL in a course of Electrical Engineering undergraduate, trying to unite multidisciplinary concepts along the course, such as robotics, programming techniques, electronics and embedded systems.

REAL CASE: NETWORK INFRASTRUCTURE

This section introduces the main aspects about the implementation of the network infrastructure, characterization of the experiment, description of the aspects about data collection, as well as the analysis of results.

Characterization of the Experiment Subjects

In this experiment, four undergraduate classes of a Network Infrastructure Design course in a private Brazilian university were considered. These classes were composed in average of 20 students during the first and second semesters of 2015 and 2016. These students were assigned with a project aiming to design the physical and logical infrastructure of a computer network. The students of the semesters 2015.1, 2015.2 and 2016.1 were exposed to a traditional methodology for the Network Infrastructure Design course, meanwhile the 2016.2 class, an experimental group, was required to follow the methodology depicted in **Figure 1** throughout the whole semester.

PBL Applied to Network Infrastructure Design Course

The PBL methodology adopted in this work was adapted from (Ribeiro, 2008), which consists in a sequence of steps based on problems (**Figure 1**). The first step of the methodology is the introduction of a specific problem, presented by the tutor (teacher or professor) and analyzed by groups of students (Step 1). After presentation and problem analysis, the students, assisted by the tutor, discuss and raise possible causes of the problem and potential solutions for it (Step II).

In Step III students evaluate the proposed hypothesis based on the information extracted from the problem and try to come up with a solution based on previous knowledge. This step is an opportunity for students to present their concepts being built related to the respective subject, guided and strengthened by the tutor, by the group of students or by individuals.

When students are not successful to come up with a solution to the problem with the knowledge they already possess, they try to identify the learning issues or standpoints (concepts, theories, etc.) required to solve it (Step IV). After that, during Step V student plan group work (which points should be prioritized? Who will make a research about it? Which information sources will be applied? When, how and where the new information will be made available?). In Step VI students apply the knowledge acquired during problem solving as many times as required in order to achieve a reasonable solution agreed by all the members of the group. The final step of this problem-solving cycle is related to the production of a document describing all the proposed solution for the problem, which will be presented to the tutor and all the other groups (Step VII). The cycle is complete when students are able to assess the process, the final product, the group work, its own performance and that of the remaining members of the group (Step VIII).

In order to carry out the experiment proposed with the methodology previously introduced, the professor had to modify the way he/she introduced the problem to the students in the hands-on class (laboratory). Thus, based on a real and specific need identified in a real-life situation, the professor was able to propose the development of a simulated environment for discussion and resolution in class in order to find out solutions to be applied to the real non-controllable environment.

Therefore, the following PBL steps were applied to this project:

- Step I: The problem/project chosen for the discipline being studied played a key role in order to motivate students. Thus, the participation of students was required in order to solve real problems bound from real-life needs. The proposed project was related to the design and implementation of a computer network infrastructure in a public Brazilian high-school with up to 1500 users. During the design of the infrastructure some other key aspects were considered such as sustainability and social responsibility in order to decrease the impact of the development costs.
- Step II: After the definition of the problem, students, under the guidance of a professor, came up with hypothesis that could be helpful to solve the problem. These hypotheses were related, for instance, to the characterization of the physical space, identification of potential users, types of applications regularly applied by users, budget limits, etc.
- Step III: With the hypothesis clearly defined, students tried to provide answers intuitively and predict possible results for the solution of the problem based on their previous knowledge. These answers were in general related to the requirements identification obtained in Step II.
- Step IV: In this step the professor had already the opportunity to present all the concepts of the course that had been covered by the students so far or which they had a previous knowledge about. These concepts were in general related to the definition of standards, cabling solutions, traffic dimensioning, among others.
- Step V: In this step students planned the group work based on the problem to be solved and on the new knowledge acquired. Specifically in the case of the implementation of a network infrastructure the following activities were carried out: specification of the wireless LAN (Local Area Network), technical specification of the equipment to be acquired, budget definition and costs of the equipment, among others.
- Steps VI and VII: Once the concepts were discussed and understood, students were able to produce a descriptive memorial of the project describing the following components:
    - Project, which presents the results of the identification of the technical requirements, such as dimensions of the building, characterization of the physical space, distribution of the network outlets, active components (communication equipment, such as routers and switches) and passive components (such as cabling, outlets, racks, patch panels, etc.).
    - Budget with a list of materials and respective costs for the implementation of the project.
    - Design of racks.
    - Addressing schema.

Table 1. Results for classes of 2015.1 through 2016.2

Year/Semester	Average Grade	Average Absence
2015.1	7	5
2015.2	6	3
2016.1	7	2
2016.2	8	1

  - Logical design.
  - Physical design.
- Step VIII: In this step the professor of the course carried out some informal interviews with students in order to have a perception of the work being developed. At this moment it is possible to assess qualitatively the learning process for each student and each group. One of the issues noticed in this evaluation was how the problem was proposed and which was the adopted solution that has been a motivational aspect during learning process for students. This analysis was complemented with a comparative assessment of quantitative data related to the attendance and grading among students of different classes (comparing the utilization of the traditional learning methodology and PBL).

Next section presents the data collected and its respective analysis in order to assess how the PBL methodology affected students´ learning process.

Data Analysis

In order to assess how students were able to learn with the application of the PBL learning methodology, it was important to compare the learning results with some other classes from semesters 2015.1, 2015.2, 2016.1 and 2016.2. The average of students observed in these semesters was of 20 students per semester, excepted for the drop-out students. In this case, the classes of semesters 2015.1, 2015.2 and 2016.1 were exposed to the traditional learning and teaching methodology (expositive and laboratory classes). In the opposite, the 2016.2 class was exposed to the PBL learning methodology as a motivational aspect in order to enable students to implement a computer network infrastructure in a public school, as a case study.

In order to assess the learning results, a comparative approach was carried out considering the following metrics:

- Attendance, which allows the evaluation of the degree of commitment of a student with the proposed methodology.
- Grades, which still represent one of the main metrics applied to assess learning related to a subject presented during academic term.

These metrics were obtained from the university´s electronic grading system for each one of the respective semesters. Based on these data, the average values could be calculated in order to determine the evolution of each group. **Table 1** presents the comparative data for the average calculated based on the metrics applied.

As it is possible to observe on **Table 1**, according to the average grade (in a 10 point scale) related to the evaluated semesters (2015.1 until 2016.1) using the traditional learning methodology, there was an unexpressive grading pattern along these semesters. However, after being exposed to the PBL methodology, the students improved considerably their grades on semester 2016.2. Therefore, the hands-on experience in a real life scenario provided a better comprehension of the subjects studied within classroom. In opposite, another metric observed was the student´s attendance, which allows the evaluation of the degree of commitment a student has with the proposed methodology. Similarly the attendance also presented a pattern along semesters 2015.1 through 2016.1. However, this pattern was modified within semester 2016.2 after the application of the PBL methodology. This modification indicates that the proposal of hands-on experiments within real life scenarios was a motivational key to improve student´s participation and commitment with the course. This motivational burst was not observed on the previous semesters when the PBL methodology has not been applied. The execution of this study enabled us to observe that students exposed to PBL methodology were able to associate broadly the theoretical content studied within classroom with the experiment applied according to the needs of the professional life. This association provided them with a clear maturity related to the subject studied, and as a consequence, with a higher commitment with the execution of the project.

RESULTS AND DISCUSSION

The results of the classes obtained in each semester require an evaluation concerning the adopted teaching methodologies and their real contribution to the learning results. Therefore, two main issues are considered: the attendance behavior of the students within classroom during semester, which denotes their degree of commitment

with the learning process, and; the grading results of students, which despite presenting some drawbacks in order to denote learning results, it is still the main metric applied by high education institutions in order to assess learning. In this context, according to the analysis of the previous metrics (attendance and grades), we can clearly verify that betters results were obtained in the semester 2016.2, when a real life problem was applied to illustrate the utilization of the PBL learning methodology. According to the results observed, 50% of the students obtained grade 8,0 compared to the average grade of 6,6 during semesters 2015.1, 2015.2, 2016.1. As already mentioned, the behavior of the classes in each semester raises the importance of an assessment about the teaching methods and their real contribution to the learning process. Two main issues are considered: The behavior concerning the attendance of students within classroom during the semester, which can be related to the degree of commitment with learning, and; the student's evaluation results, which is highly applied by the higher education institutions as the main learning assessment tool, even though it is limited when it comes to perceive learning. Therefore, the analysis of both criteria (attendance and evaluation results) demonstrates better results in the semester 2016.2 where a realistic problem for the development of a PBL learning process was applied. The results indicate that 50% of students obtained grades above 8,0 compared to the average grade of 6,6 during semesters 2015.1, 2015.2 and 2016.1 when students had grades of 7,0, 6,0 and 7,0 respectively. Considering the attendance among classes, it is also possible to observe better results after the application of PBL to a realistic problem, since in 2016.2 the average of absences is 1, in other words, 50% of students were absent only once during the whole semester. Nevertheless, in the previous semesters (2015.1, 2015.2 and 2016.1) the average of absences is 3, which denotes that 50% of students were absent at least 3 times during the whole semester. Besides the changes observed related to grades and attendance on the studied classes, the faculty involved with the project also could notice the change in behavior and awareness of students. Even though this perception is subjective, it allowed faculty to make an analysis concerning the application of the PBL methodology during the learning process. In order to facilitate this analysis, this perception is defined under two different standpoints, the professor who applied the PBL methodology and the other professors who are responsible for other courses during these semesters:

- Faculty members involved in the project: a higher commitment was observed during theoretical classes, observing that students were able to correlate subject studied within theoretical classes with TP classes, understanding their importance in their daily utilization. Therefore, students demonstrated an improved ability to solve problems, always searching extra knowledge beyond those taught in classroom. Another valuable issue was how students developed their social awareness participating in a real community project.
- Faculty responsible of other courses: the commitment with issues related to digital inclusion was unanimously observed, besides their interest to develop a systematic observation about Communication and Information Technologies, contributing to a better understanding and learning of other courses. Also, they could observe how students develop their autonomy, motivation, team working abilities and ability to evaluate requirements in real life projects.

FINAL CONSIDERATIONS

This paper discussed the impact of the application of PBL methodology in the learning process applied to the demands of real life related to an undergraduate Network Infrastructure Design course. The students participated in a case study oriented to the design and implementation of the physical and logical project of a network infrastructure for 1500 users of a public school. Among the main results observed by the professors, according to the reports and to the follow-ups of students during activities related to the project, the adoption of PBL in the Network Infrastructure Design Course allowed students to develop the following skills:

- Identify the relevant aspects about the problem being studied carrying out important discussions within the context of the project.
- Acquire autonomy to design and implement a complete computer network infrastructure project.
- Build a complete knowledge base in order to support the definition and management of problems due the implementation of computer network infrastructure.
- Develop a logic reasoning including analysis and synthesis.
- Carry out a critical evaluation of information concerning the problem.
- Develop the ability to communicate with public, and;
- Develop the ability to carry out critical evaluation of problems due the implementation of a computer network infrastructure.

It was also possible to observe that when the problem (project) was introduced to the students, they felt concerned about having a passive role in the learning process, where only the professor owns the knowledge. This problem was overcoming as the experimental phase was over and the students carried out an active role in their learning process. During several informal interactions with the students, the professor recognized their motivation,

in particular when they learned that the proposed infrastructure would be applied by a high number of users, which presents the same technical complexities, or even higher, as in many companies that need to apply the network infrastructure as an strategic factor in their business.

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