Teaching Physics for Engineers using an Active Learning approach

Rodrigo Cutri¹, Luiz Roberto Marim², José Roberto Cardoso²

Maua Institute of Technology¹, University of São Paulo²

rodrigo.cutri@maua.br, marim31415@gmail.com, jose.cardoso@poli.usp.br

Abstract – The teaching technique of project-based learning (PBL) has been part of the academic curriculum for sophomore Engineering students of Maua Institute of Technology since 2014.

Such an approach, which required substantial changes in the teaching and learning methods, had a significant impact on students' learning and motivation. Every year a new PBL project is proposed. As part of the evaluation process, reflecting on the past experiences and merits of the PBL experiences is very important.

After presenting the overview of PBL in the context of teaching Physics, we discuss in this paper the merits of this approach by analyzing the quantitative and qualitative survey results of the last three PBL editions.

Keywords: Physics, Soft skills, Active Learning, Project-based Learning

1. INTRODUCTION

Usually, students have several misconceptions related to Electricity and Magnetism [1-5], to overcome this difficulties and promote a better understanding of Physics concepts, Maua Institute of Technology adopt active learning techniques, such as project development through project-based learning (PBL) in teaching Physics methodologies. PBL approach develops numerous skills, such as critical thinking, information processing, analysis, reflection, and questioning [5-9].

PBL has been part of the academic curriculum for sophomore Engineering students of Maua Institute of Technology (an universe of 1000 students - 700 Day / Night 300), since 2014 [5],[10],[11]. In PBL approach, each student group (four members) must develop, in extra-classroom work, a project in the academic semester. The project must use electromagnetic or wave concepts. At the end of semester, each team must perform an oral examination, done by laboratory teacher, to evaluate whether the students understood the Physics concepts. The PBL project composes 25% of a student's annual lab grade.

For the past three years, the PBL approach was used in the implementation of three main projects: 2014-Electromagnetic Crane, 2015-Wind Generator, and 2016-Free Video Competition.

In each case, the evaluation of the activities developed by the students was done through an analysis of the project development. The teacher analyzed the students' ability to identify the variables of the problem and optimize them, their understanding of the Physics concepts, and their skills in developing adequate scientific tests to improve and verify their results.

2. PBL PROJECTS CHARACTERISTICS

All three projects [5],[10] are open-solution projects guided by the concept of PBL. Learning objectives are:

- Verify electromagnetic applications daily.
- Develop a project and analyze it using a scientific method.
- Identify variables and optimize them.

Table 1 summarized a brief description of each project:

Table 1: Brief description of developed PBL Projects.

PBL Project	Description	Competition rule
2014: Electromagnetic Crane	Each team must construct, and evaluate an electromagnetic crane for a clip lifting activity.	The team in each laboratory that is able to attract the greatest possible quantity of clips, will earn an additional 1.0 point in the overall evaluation of the semester project. If there is a draw, both groups will benefit.
2015: Wind Generator	Each team must develop a Wind	The team in each laboratory that is able to generate the highest potential

	Generator.	voltage between the generator terminals, regardless of the attempt, will earn an additional 1.0 point in the overall evaluation of the semester project. If there is a draw, both groups will benefit.
2016: Free Video Contest	Each team must develop a video about an experimental demonstration about Electromagnetism and Waves. Experiments previously done in class cannot be repeat.	The team in each laboratory that gets most likes in YouTube Channel will earn an additional 1.0 point in the overall evaluation of the semester project. If there is a draw, both groups will benefit.

In all projects, the evaluation of the process is just as important as the final outcome. Students must identify variables and seek ways to optimize them. Hence, they are expected to employ scientific methods in designing and performing empirical tests.

3. PBL EVALUATION

To evaluate if the PBL projects were effective, a qualitative and a quantitative survey, using the blind process, was applied to students during all this years.

The comparative analysis of qualitative characteristics shows that:

- Promote more creative projects (2016 edition) increases motivation, besides more resources and efforts for students;
- Using real and actual problems in project themes was very interesting;
- Oral examination and presentation was an excellent way to evaluate students;
- Competition was a great motivation factor for student's teams to exert more effort in the study of project optimization and improvement besides the small grade increase;

- Teachers must not be worried about ideas, must only began to work with PBL approach. Student's always surprises if they are motivated.

Figure 1 presents a qualitative comparison of each PBL edition.

Fig. 1. Qualitative Edition Analysis.

Figure 2 presents positive student's perception in a quantitative comparison of each PBL edition.

Fig. 2. Quantitative Edition Analysis.

As can be seen in Figure 2, change to a model wherein the students had free choices among themes, the students' interest and understanding increased.

Table 2 summarizes student's perceptions. The principal positive aspects that are put in evidence are motivation; reinforcement; understanding. In addition, the principal negative aspects are overload; not guided project.

Table 2: Students perceptions of developed PBL Projects.

Good Student perceptions
<p>"Every year, rather than a laboratory test, the grade should be based on this work, as it was this year, because it makes understanding much easier and more simple"</p> <p>"We learn from mistakes after submission"</p> <p>"The students' need a better organization of their time"</p> <p>"Very interesting project"</p> <p>"The work has helped improve our knowledge"</p> <p>"The activity appeared very effective in demonstrating the physics concepts applied in the engineering world"</p> <p>"The project was extremely important, because the concepts we saw in class were reinforced"</p> <p>"We are happy, because we did it"</p> <p>"We could do"</p> <p>"Creativity motivate us"</p> <p>"It is was cool to put it in Youtube"</p>
Bad Student perceptions
<p>"Overloaded with other jobs"</p> <p>"Better a theme for each group"</p> <p>"Overloaded with other disciplines"</p> <p>"Some questions had more than one interpretation"</p> <p>"Work should be shorter and have objectives"</p> <p>"Avoid abstract themes"</p> <p>"It's hard to choose that to do"</p>

"Competition is not fair"

Grade comparison among students is difficult to carry out because students vary as do the projects they join. Still, during the evaluation process—whether in exam tests or in the oral evaluation of the project—students were better able to evaluate and explain when they possessed a better concept-level understanding of the subject. This demonstrates the qualitative increase in the cognitive skills required of the students.

From interviews conducted with the teachers, it can be observed that conceptual gains surpassed written test scores. Moreover, the students also improved their communication skills and teamwork, which are important in the practice of engineering. Oral evaluation, despite being less homogeneous (given the need to diversify the question repertoire among groups) also allowed for a better analysis of the students' performance and involvement by demanding active participation instead of mere attendance.

3. FINAL CONSIDERATIONS

The use of active learning methodologies, such as PBL, demonstrated positive results with students demonstrating a better understanding of the relationships between the concepts and the practical applications in their engineering projects. Moreover, students showed greater commitment to the idea.

References

- [1] Advanced Electromagnetics, Vro.1, Nr.1, Md 2012 Difficulties in teaching electromagnetism: an eight year experience at Pierre and Marie Curie University H. Roussel, M. Helier
- [2] Kristina Zuza, José-Manuel Almudí, Ane Leniz, and Jenaro Guisasola. Addressing students' difficulties with Faraday's law: A guided problem solving approach Department of Applied Physics, Polytechnic University College of Donostia, University of the Basque Country, 20018 San Sebastian, Spain - PHYSICAL REVIEW SPECIAL TOPICS - PHYSICS EDUCATION RESEARCH 10, 010122 (2014)
- [3] Cristian Raduta, General Students' Misconceptions Related to Electricity and Magnetism Physics Department The Ohio State University Advisor: Prof. Gordon Aubrecht - <http://cds.cern.ch/record/828008/files/0503132.pdf>
- [4] Yehudit Judy Dori & John Belcher Department of Education in Technology and Science Technion, Israel Institute of Technology, Haifa 32000, Israel 2 Center for Educational Computing Initiatives, Massachusetts Institute

of Technology Cambridge, MA 02139, USA 3 Department of Physics, Massachusetts Institute of Technology Cambridge, MA 02139, USA Learning Electromagnetism With Visualizations And Active Learning - http://web.mit.edu/jbelcher/www/TEALref/Chapter8_Dori_Belcher_FINAL_8_12_2004.pdf

- [5] Cutri,R.; Baracat,D.; Witkowski,F.M.; Megrich,A. O uso do ensino baseado em problemas para a disciplina de Física (Eletromagnetismo e Ondas) num Curso de Engenharia. Project Approaches in Engineering Education - PAEE'2013, Eindhoven, Holanda. July 8–9, 2013
- [6] Du,X; De Graaff,E.; Kolmos,A. Research on PBL Practice in Engineering Education. Sense Publishers. 2008
- [7] Goodhew,P. Teaching Engineering - All you need to know about engineering education but were afraid to ask. The Higher Education Academy UK Centre for Materials Education, September 2010
- [8] Dori, Y.J.; Belcher, J. Learning Electromagnetism with Visualizations and Active Learning. Visualization in Science Education. Models and Modeling in Science Education. Volume 1, 2005, pp 187–216
- [9] Fraser,J.M.; Timan,L.A.; Miller,K.; Dowd,J.E.; Tucker,L.; Mazur,E. Iop Publishing–Reports on Progress in Physics–Doi 10.1088/0034-4885/77/3/032401, 2014.
- [10] Cutri, R., & Baracat, D. E., & Marim, L. R., & Witkowski, F. M., Active Learning for Physics (Electromagnetism) Teachers in an Engineering Course 2015 ASEE Annual Conference and Exposition, Seattle, Washington. 10.18260/p.23486
- [11] Cutri, Rodrigo; Baracat, D. E.; F.M. Witkowski; Marim, L. R. . Avaliação do uso da metodologia PBL para a disciplina de física (eletromagnetismo e ondas) num curso de engenharia. In: Congresso Brasileiro de Educação em Engenharia (COBENGE), 2014, Juiz de Fora.