Active-learning for Physics (Electromagnetism) teachers in an Engineering Course

Prof. Rodrigo Cutri P.E., Maua Institute of Techonology

holds a degree in Electrical Engineering from Maua Institute of Technology (2001), MSc (2004) and Ph.D. (2007) in Electrical Engineering - University of São Paulo. He is currently Titular Professor of Maua Institute of Technology, Professor of the University Center Foundation Santo André, and consultant - Tecap Electrical Industry Ltda. He has experience in Electrical Engineering with emphasis on Industrial Electronics and Engineering Education, acting on the following topics: power electronics and active learning.

Mr. Demetrio Elie Baracat DEB, Centro Universitário do Instituto Mauá de Tecnologia

Mechanical Engineer, PhD and MSc in Engineering from EPUSP - Brazil, Post-graduate in Accounting & Financial Management and in General Management from Getúlio Vargas Foundation of São Paulo (FGV-SP).Teacher at Centro Universitário do Instituto Mauá de Tecnologia - São Paulo - Brazil in the disciplines Calculus II and Evaluation and Selection of Heat Exchange Equipment. Co-chairman in Academic SAE Brazil Congress

Dr. Luiz Roberto Marim, Maua Institute of Technology

Graduated in Bachelor of Mathematics by the Foundation University Center Saint Andrew (1985), Graduate Degree in Physics from the University of Taubaté (2000), master's degree in Physics from the Technological Institute of Aeronautics (2002) and a PhD in Physics from the Technological Institute of Aeronautics (2006). I am currently associate professor of Maua Technology Institute and collaborator professor at the Institute of Aeronautical Technology (ITA), acting on the following topics: silicon, genetic algorithm, artificial neural networks and physical Olympics.

Dr. Francisco Mauro Witkowski, Instituto Maua de Tecnologia

Graduation in Physics - Universidade de São Paulo - 1969 Master in Physics - USP - 1972 Ph.D. in Physics - Instituto de Física Teórica IFT - 1976 Professor - Instituto Mauá de Tecnologia since 1988

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ABSTRACT

Students of Engineering have difficulties in the assimilation of the concepts explored in Electromagnetism and Waves. These difficulties begin with a lack of abstraction, especially when seeking to understand the Electromagnetism concepts. Many active learning methodologies and cases are presented in the literature for Classical Mechanics, but there are few references to Electromagnetism and Waves. This study presents a PBL—Problem Based Learning and a Project Based Learning—practice which was applied to a large class (25 students) and replicated for a thousand student universe in an annual university physics class. In the Problem Based Learning approach, each semester, four students teams received, contextualized scripts (with problems for which they were required to conduct simulations and provide conceptual analysis) (see example in the Appendix); at the end of each semester, they presented their results in an oral presentation and had an oral evaluation test. In Project Based Learning approach, at the end of the academic year, the same teams worked together on a final open project using electromagnetics concepts (project, construct, and evaluate an electromagnetic crane with open specifications) and participated in a competition. The active learning development pedagogical process was used to allow students to have a better understanding of physical phenomenon, in addition to developing scientific thought to allow for suitable modeling, simulation, and analysis, without only doing mathematical deductions with no understanding of Real Physics. The evaluation of the learning process was done using a close- and open-ended questionnaire survey completed by the students at the end of the semester. Students, using a blind process, had the opportunity to evaluate how the proposed activities allowed them to achieve a better understanding of the physical concepts, such as if this increased their motivation for engineering, if the amount of time available to solve problems was adequate, if the support provided for the development of the work (infrastructure and service teachers) was used, and any suggestions they had for improvement. The survey results revealed that the students' perception of their understanding increased, with approximately 70% of students approving of the new pedagogical proposal. This same

idea could be easily applied in other engineering schools by adapting the contextualized scripts.

Keywords: PBL, Electromagnetism and Waves, Engineering Education

Introduction

Engineering students have difficulties in assimilating the concepts explored in Electromagnetism and Waves. These difficulties begin with the students' lack of abstraction, especially when seeking to understand Electromagnetism concepts. Many active learning methodologies and cases are presented in the Classical Mechanics research, but there are few references for Electromagnetism and Waves. Since 2013, the Physics course in Maua Engineering School has used an innovative method for teaching the concepts of Electromagnetism and Waves in the Engineering Courses, which allows the student to gain a deeper understanding of Physics Concepts[1].

Characteristics of the developed project

All projects were applied to all students in the basic cycle (2nd year of Engineering Course – Basic Physics) of the discipline Physics II (Electromagnetism and Waves) and were aimed at the following:

- using an active learning approach[2,3,4];
- promoting a better interpretation of physics and its application in practical situations[5] promoting activities where students can understand how physics works instead of just doing calculations;
- developing skills and competencies for a professional life as an Engineer[6], such as gaining an understanding of different cultures, foreign language skills, oral and written expression, time management, and teamwork, amongst others.

The pedagogical features of the developed project were as follows:

- development of scientific thinking and reflection using physical problems.
- application of real problems with increasing difficulty levels;

• development of skills in simulation, analysis, and modeling.

Characteristics of the structure of the developed project:

• working in groups;

• application problems that make use of prior knowledge (already acquired in classes) and new knowledge (which would still be exposed later);

• use of sequential scripts with a backstory;

• integration with other basic sciences;

• teacher as facilitator and moderator of activities;

• number of students undergoing activity: 1000 (65% enrolled in morning courses and 35% in evening classes);

• number of students per team: 04

• all extra classroom work with supervision and evaluation by laboratory teachers.

The project used both Problem and Project Based Learning approaches. Problem Based and Project Based approaches were used in the same student's teams. In 1st semester were used only Problem approach (with simulations and analysis) and in the 2nd semester, were used Problem approach by scripts and Project approach by competition with an open project solution.

In the Problem Based Learning approach, each semester four student teams received contextualized scripts (with problems for which they were required to conduct simulations and provide conceptual analysis) (see example in the Appendix), and at the end of each semester they presented their results in an oral presentation and had an oral evaluation test. The activities were proposed through scripts linked by a common story that allowed the exploration of the following concepts: electrostatics, electric fields, potential, capacitance, magnetic fields, electromagnetic forces, Faraday's law, electromagnetic induction, oscillations and waves, and related topics to the Fourier series transformation.

In Project Based Learning approach, at the end of academic year, the same team worked on a final open project using electromagnetics concepts (project, construct, and evaluate an electromagnetic crane with open specifications) and participated in a competition for a clip lifting activity.

The winning Team, which received a plus grade in evaluation, was the one that attracted the greatest possible quantity of clips.

The following rules had to be observed:

1. The construction of the crane could be made with any type of material.
2. It needed to use two 1.5 V batteries as the energy source.
3. The crane had to lift metal clips (N°. 03) using only magnetic attraction, and any form of mechanical lift was prohibited .
4. The crane should not be higher than 1 m.
5. The failure of the crane (the electromagnet does not attract any clips) resulted in a zero score for the team.

An example of the conceptual developed project analysis is presented in Appendix B.

The Problem Based Learning approach scripts were applied all year (4 in 1st semester and 3 in 2nd semester). Each semester had evaluation tests. The Project Based Learning Prototype was developed during 2nd semester and presented near the end of semester, before the final tests.

Evaluation

There were two evaluation stages in the project. The first was an evaluation of the activities developed by the students and the second was the assessment of the learning process proposed by a team of teachers:

Evaluation of the activities developed by students

The lab grade was divided into two; 50% for the weekly reports required all academic year, and 50% for the PBL Projects. The PBL Project grade was also divided into two, with 50%

for the Problem Based Learning Approach and 50% for the Project Based Learning Approach (Crane Competition).

Problem Based Learning evaluation grades

The evaluation for the activities developed by the students was composed of grades given by the teacher for the work (40%) and an oral evaluation of the student and their group (30%) and a portfolio of activities (30%). The grade consisted of three items: self-assessment, portfolio analysis, and oral presentation evaluation. The oral presentation was 10 minutes or less with a maximum of 10 slides. This restriction aimed to develop in students the ability to select relevant results and present them in an objective way. The first grade, self-assessment, allowed each member of team to evaluate themselves and others. The second grade evaluated the organization and project presentation and third grade evaluated each student individually in an oral test.

Project Based Learning evaluation grades

The evaluation of the activities developed by the students was done through an analysis of the project development. The teacher analyzed if the students were capable of identifying what the variables of the problem were, their understanding of the physics concepts and their ability to develop adequate scientifically based tests to improve results.

Evaluation of the proposed learning process

The evaluation of the proposed learning process was done through a survey which was completed by all teams. Using a blind process, the students evaluated the activities. The tabulated answers are presented in Table 1 and the suggestions for improvement in Table 2.

Table 1: Responses of students

	Period	Night			Day		
		70			112		
	Question	Yes	No	Indifferent	Yes	No	Indifferent
1	The presented cases were interesting?	84%	1%	14%	72%	1%	27%
2	Do you consider that understanding physical concepts is critical for an engineer?	94%	0%	6%	98%	0%	1%
3	Did the cases allow you to see applications of physical concepts in engineering applications?	89%	1%	10%	85%	2%	13%
4	Was the amount of activity appropriate?	70%	3%	27%	79%	3%	18%
5	Was the time between activities (presentation at the end of each semester) adequate?	80%	1%	19%	81%	2%	17%
6	Did the group seek guidance* from the project with teachers from the discipline?	41%	26%	33%	37%	30%	33%
7	Did the group seek guidance* about the project from student monitors?	11%	79%	10%	5%	85%	10%
8	Did this work provide a better understanding of the subject Physics?	70%	1%	29%	73%	2%	25%

*guidance=extra class help

Table 2 - Student perceptions

Bad	Good
"Missing subtitles in videos" "Exercises should be more direct" "Overloaded with other jobs" "Better a theme for each group" "Overloaded with other disciplines" "Some questions had more than one interpretation" "Extensive Roadmaps" "Work should be shorter and have objectives" "Avoid abstract themes" "The discipline already has a large workload, and roadmaps require a long time to make"	"The simulations gave a lot of help in the understanding of physical phenomena and were interesting because of the easy handling of the system." "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" "We learn from mistakes after submission" "The students' need a better organization of their time" "Very interesting project" "The work has helped improve our knowledge" "The activity appeared very effective in demonstrating the physics concepts applied in the engineering world" "The project was extremely important, because the concepts we saw in class were reinforced"

Difficulties and the results obtained through the development of activities

Initially students had difficulties in interpreting what they really had to do because they were not used to PBL activities. However, the proposed approach enabled computer simulations to assist in the physical interpretation and analysis which promoted a better understanding of the Physics concepts. Also, the practical activities, such as the electromagnetic crane and the competition, increased motivation. According to the survey conducted with the students from both the day and night classes, the perception of understanding was said to have improved by

70% of the students, while 20% were indifferent and 10% claimed the proposed model had no effect.

The comparative grades for 2013 and 2014 were higher, but there was a decrease in retention rates of 10%. The written exam showed similar difficulty levels in both years, but students demonstrated a better understanding of conceptual physics analysis.

In authors' perceptions, most successful results are related with student's motivation in Physics Class. Student´s commitment along the academic year improved because they became to see more clearly the relationship between Physics and real world projects. Also teacher's team improved theirs learning approach, some teachers have never worked with PBL (project or problem) approach. In our school, teacher's teams are composed by Physician and Engineer teachers, so it was an opportunity to exchange applications of physics concepts.

Next time it is intention of authors to make a practical project also in 1st semester, and change some problems activities. This every year change is necessary to avoid "copy and paste" students' practice from one year to other.

Implement similar activities in others schools demands first teacher's team commitment. It's not difficulty to develop activities but demand time and work.

Final

The use of active learning methodologies was very positive with students demonstrating a better understanding of the relationships between the Physical concepts and the practical applications of engineering results. Students showed a greater commitment to the idea, so, according to the suggestions made by the students themselves, in 2015, a deployed version will be adopted and used in practical activities in 1st semester.

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APPENDIX

5º SCRIPT

Learning Objectives • Explore the magnetic field applications

The group is invited to meet about a special High Speed Train (Maglev) project. On entering the special projects room, they are welcomed by the general manager of the project. After an explanation of the project, they see a 3D virtual model of the MAGLEV and learn details of the construction of the train and the control module. A phrase in the living room wall catches their attention: “No brain, no gain..” When they leave, they are excited because they have assisted in a direct application of the concepts of electromagnetism they had learned in Brazil. They are also reminded that the Brazilian government plans to build a high-speed train linking Rio de Janeiro to São Paulo.

1) Watch a video on youtube about the Maglev.

2) Visit the film at: http://www.mip.berkeley.edu/physics/levitator.html - Copyright © 1991, 1996 By the UC Regents. Explain physically what happens in each film.

3) Demonstrate mathematically the Biot-Savart Law in a rectangular conductor loop format and calculate the magnetic field at its center.

4) In the following situations, use the simulations arranged:

http://web.mit.edu/8.02t/www/802TEAL3D/index.html (Copyright MIT TEAL / Studio Physics Project), presents a graphic display of the screen and explain physically what happens with: a) the magnetic forces between the parallel conductors carrying the current in the same direction; b) the magnetic forces between the parallel conductors carrying current in opposite directions;

B APPENDIX

Sheet Project Date

Teacher Team Name

Design data

• Crane Arm length: _____ cm

• Drawing or photo with front and side views

• Electromagnet

Core Material: _________________

Wire Type (material and section):_____________________

Number of windings:___________________

• Power Source - general characteristics:_________________

Variables that can be changed to increase the magnetic field of the electromagnet? ____

____

Performed tests of clips lifted–Observed variable changed:

Test 1	Variable changed:	Clips lifted:
Test 2	Variable changed:	Clips lifted:
Test 3	Variable changed:	Clips lifted:
Test 4	Variable changed:	Clips lifted:

Final solution: ____

Problems and proposed solutions:____