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Project Based Learning for Electrostatics

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Abstract

This paper presents the results of the teaching strategy based in The Construction of Prototypes (TCP) and Project Based Learning (PrBL) which was applied in a course of electricity and magnetism for engineering students of two universities in Bogotá-Colombia. This research has been focused on developing three projects, namely: electroscope, Torsion Balance Coulomb, Van de Graff generator. We present our Analysis result obtained using psychometric tools such as Hake gain. In addition, the strengths and difficulties of the strategy employed compared to traditional instruction are presented.

Keywords: Project-based learning, prototypes, electrostatic.

Resumen

Este trabajo presenta los resultados de la estrategia pedagógica fundamentada en La Construcción de Prototipos (LCP) y el Aprendizaje Basado en Proyectos (ApBP) que fue aplicada en cursos de Electricidad y Magnetismo para estudiantes de ingeniería de dos universidades en Bogotá-Colombia. Este artículo se enfoca en tres temáticas: Electroscopio, Balanza de Torsión y Generador de Van de Graff. El trabajo presenta fortalezas y dificultades de la estrategia empleada en comparación con la instrucción tradicional

Palabras clave: aprendizaje basado en proyectos, prototipos, electrostática.

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I. INTRODUCTION

The program in science and engineering uses the physics in their curriculum. However, the current curriculum requires not only the accumulation and verification of concepts but of skills to train students for analysis, problem solving, and to use information appropriately according to [1]. Among the strategies to use are the research activities and final projects, so-called practical work. Our aim is to show, -following to Gil-, the importance of the physical processes through experimentation. For instance the possibility of working on activities that involve the scientific work and in the same way the application of the "scientific method" [2, 3, 4].

This research presents the results obtained in the design and construction of prototypes for electroscope (P1); Torsion Balance Coulomb (P2), Van de Graff generator (P3) in a course electricity and magnetism. Figure 1 show prototypes which were developed by students. Based on our experience in 2014 with student's projects belonging to Faculties of Engineering in the Manuela Beltrán University (MBU) and Colombian School of engineering (CSE) in Bogotá, Colombia. The paper is structured as follows: In section II we review the project-based learning. Section III we present the prototyping strategy in Electrostatics. Section IV we show the methodology used. Section V we present the results. Section VI we present the conclusions of the strategy employed.

FIGURE 1. Prototypes developed for students in Electrostatics.

II. PROJECT BASED LEARNING IN PHYSICS

This type of educational practices and project based learning activities can generate more flexible with the student's needs according to [5].

A. Elements

The basic elements according to [6] are:
a) Focus on the student.
b) Meaningful content for students, directly observable in their environment.

B. Benefits

The most important benefits of project-based learning as [7] are:
-To increase social and communication skills.
-To allow students to use their individual and collective strengths through collaborative work.

C. Structure

We present basic structures according to [8] are:
a) Situation or problem.
b) Description and purpose of the project.
c) Specifications and standards to achieve progressively.

D. Learning goals

We have identified two questions that must be taken into account according to [8] are:
a) What kind of problems do we want to be able to solve in the students?
b) What concepts and principles do we want for the students to be able to apply?

III. CONSTRUCTION OF PROTOTYPES IN ELECTROSTATICS

A. What is it?

It is a strategy based on the design and construction of prototypes that allows uses the scientific method on the development of projects. Besides the students can also activate other level skills of graphic expression, oral and written.

B. Learning goals

a) To introduce students in the process of design and construction of prototypes.
b) To engage students with the concepts of physical modeling, error theory and graphical analysis.

C. Cycle of experimentation with prototypes

The fundamental structure of experimentation with the prototypes is indicated in [9]. The methodology was used at the level of rotational dynamics as shown [10, 11, 12, 13, 14].

In the cycle of experimentation with prototypes the students submit laboratory reports. The main objectives of the reports are:

a) To generate an experimental work with questions and procedures.
b) To create a space where students build a mental representation of the phenomenon to be analyzed, before they begin working.
c) To emphasize the importance of group work by discussing the observations and results through information like graphic, verbal and written.
d) To generate in the students analysis capabilities around graphical analysis and the theory of error related to the prediction and validation of the observed phenomena.

All documents referring to this work can be downloaded from [15].

IV. METHODOLOGY

A. Objective

Measure and assess how The Construction of Prototypes (TCP) and project-based learning (PrBL) increase efficiency in and electrostatic teaching (ET), this at a course in electricity and magnetism with engineering students.

B. Justification

By introducing project-based learning in connection with the construction of a prototype it is able to measure the feasibility of its use and convenience of application from pedagogy.

C. Research questions

Do the (PrBL) and (TCP) contribute more meaningfully in the (ET) at the electricity and magnetism course for engineers?

D. Hypothesis

The (PrBL) and (TCP) has a gain on the effectiveness of (ET) compared to traditional instruction (TI) projects , since it allows the instructor to design and implement experimental work (theory of error and graphical analysis) and theoretical (physical modeling), also generating other learning at the level of graphic expression, oral and written.

E. Pedagogical strategy

In each university we work with 4 experimental groups (traditional course where students work with projects) and with 4 control groups (traditional course where students work without projects). In experimental groups the students developed three projects, (P1), (P2), (P3) .The strategy is based on bi-weekly 2-hour activities. We begin with an introduction of the strategy in the first week of classes from the theory class. For this instance are defined sub-group (3 students) and the respective topic. In the first week the students know the basic rules, evaluation (rubric), under which they will define, execute and present projects.

In [15], this is the work plan of the semester. In week 3 students did delivery of its preliminary written and oral presentation I. These two activities determine the evaluation 1 (Eva-1). At week 4, the Workshop I was oriented: Oral and Written Expression on oral presentations, written reports and articles. At week 6 we focus Workshop II: Expression Graphic on the design and prototyping in engineering (technical standards, materials etc.). By week 8 the students realize the experimental process (prediction, observation, validation) with the prototype and laboratory report detailed in section III-C. At week 10, were delivered 1 written advance and the II oral presentation. These two activities determined the evaluation 2 (Eva-2). At week 12 we oriented the Workshop III: Physical Modeling, Theory and Error and Graphical analysis. We show the main types of models and their interpretation based on prototypes developed and the analysis of experimental data. At week 14 the experimental cycle (prediction, observation, and validation) is repeated with the prototypes to strengthen the theory of error and the graphical analysis. The activities of the week 12 and 14 run from the laboratory. At week 16 in the class of theory was performed III oral presentation and delivery; likewise was received the article wrote in scientific format. These two activities determine the evaluation 3 (Eva-3). The conceptual evaluation is applied for control and experimental groups in the first week of classes (Si) and last week (S_f).

F. Evaluation

Strategy (PrBL) and (TCP) to the (ET) have two types of evaluation, one is the evaluation of projects ((Eva-1), (Eva-2), (Eva-3)) in subgroups of 3 students and the other is the conceptual multiple-choice test that is individual, (S_i) and (S_f).

TABLE I. Evaluation Criteria for (Eva-1), (Eva-2) and (Eva-3).

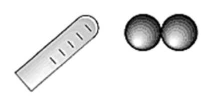
(Eva-1)	Value	N	B	R	G	E
1. Written Expression	20	0	4	11	16	20
2. Oral Expression	20	0	4	11	16	20
3. Graphic Expression	20	0	4	11	16	20
4. Experimental Cycle	30	0	5	11	25	30
5. Feedback	10	0	2	6	8	10
Score						

E: Excellent; B: Good; R: Regular; P: Poor; N:none

The evaluation project is structured according to:
a) (Eva-1): Definition of the proposal: (Week 3: value: 8%).
b) (Eva-2) Rationale of the project: (week 10: value: 10%)
c) (Eva-3) Final Results: (week 16: value: 12%).

For the three evaluations were handled the same evaluation criteria and was assessed the oral expression and the written expression; likewise the aspects such as the prototype experimental cycle and feedback. The evaluations are scored on 100 points and students could know in advance the criteria for evaluation. The criterion for evaluation is showed in figure 2 and the rubric is available in [15]

The Conceptual test for its part consists of 30 questions that were extracted and translated of the question bank of Mark Riley. The questionnaire has questions for each of the thematic of the projects (P1), (P2), (P3). The result of the evaluation for projects is 30% of the final grade and the result of the final proof of concept has a value of 5% of the courses Physics (Electricity and Magnetism) for students in engineering programs at both universities. The conceptual test of electrostatic, refer to reference [16]. The figures 3 show the question 8 of the test.



If you bring a negatively charged insulator near two uncharged metallic spheres that are in contact and then separate the spheres, the sphere on the right will have
A) no net charge.
B) a positive charge.
C) a negative charge.
D) either a positive or negative charge.
E) None of these is correct.
Ans: C

FIGURE 3: Example of question.

G. Population

The pedagogical strategy (PrBL) and (TCP) in the (ET) was applied to 8 groups (experimental group) where 4 groups (144 students) belong to the (MBU) and 4 groups (144 students) belong to the (CSE). Each group consists of approximately 40 students. Subgroups were formed later with 3 students and exceptionally 4 students. In the case of (MBU) 40 subgroups were consolidated, in the case of (CSE) were formed 40 subgroups. Additionally there were 8 groups to which were applied traditional instruction (TI) (Control Group).

V. RESULTS

A. Results for evaluation of projects, $(Eva3)$, $(Eva1)$, and conceptual multiple-choice test, S_f and S_i.

Using Hovland's concept of gain, Hake defined the gain g by equation (1) [17].

$$g = \frac{S_f - S_i}{100 - S_i}. \tag{1}$$

Where g=0 if (S_i) =100; (S_f) (Post-Test) corresponds to the conceptual test applied after applying the strategy (PrBL) and (TCP) to the (ET). (S_i) (Pre-Test) corresponds to the entrance test without applying any strategy or traditional instruction (TI). We proceeded to determine the average gain of each of the 4 experimental groups and 4 control groups before and after applying the strategy and traditional instruction in (CSE) and (MBU).

Ordering the equation (1) we have the equation (2) for evaluation for projects.

$$g = \frac{(Eva3)-(Eva1)}{100-(Eva1)}. \qquad (2)$$

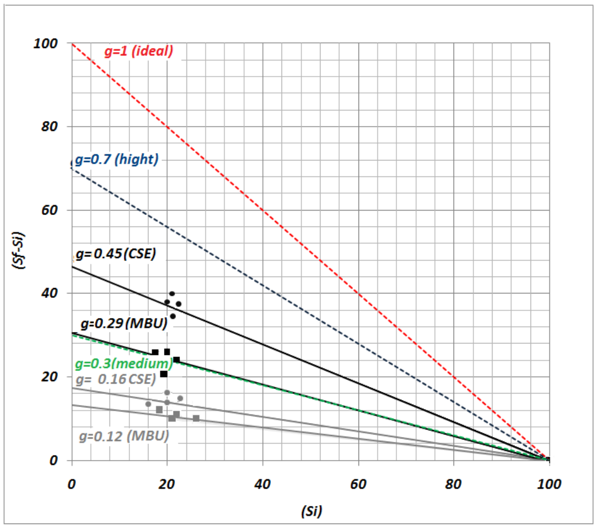


FIGURE 4: Experimental (black) and control (gray) groups (CSE, MBU), red (ideal: g =1), blue (hight: $g \geq 0.7$), green(medium: $0.7 > g \geq 0.3$), low($g < 0.3$).

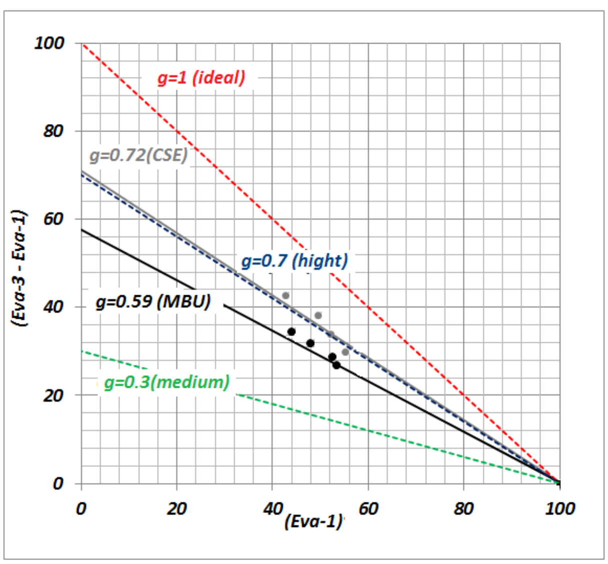


FIGURE 5: Experimental groups for MBU (black) and Experimental groups for CSE (gray), red (ideal: g =1), blue (hight: $g \geq 0.7$), green(medium: $0.7 > g \geq 0.3$), low($g < 0.3$).

Based on theoretical Fundaments of Hake, the mathematical models were obtained for each educational process. Figure 4 shows all groups (control and experimental) in (MBU) and (CSE), indicating the gain and the classification provided by [17]. Figure 4 also shows that the gain for the (MBU) with (PrBL) is (0.29 $\pm$ 0.031) and is located in medium gain, but with (TI) is (0.12 $\pm$ 0.016) and is located in low gain. For (CSE) with (PrBL) is (0.45 $\pm$ 0.021) and is located in medium gain, but with (TI) is (0.16 $\pm$ 0.018) and is located in low gain. The results show the efficiency of (PrBL) in contrast to the (TI) at both universities.

VI. CONCLUSIONS

For the three projects (P1), (P2), (P3) and for two universities (MBU) and (SCE) we state that students: Worked actively and collaboratively in the implementation of projects. Could establish a process for testing (prediction, observation, and validation) with the prototypes developed. (Although the study of the electrostatic).

The students recognized variables and constants in the physical models involved in the prototypes. Was used in a manner acceptable the error theory and graphical analysis. It showed that the oral and written presentations of design and construction of the prototype are of great importance because this prepares students in their daily work.

Finishing the projects (P1), (P2), (P3), based on the results observed in (MBU) and (SCE) showed that students took into account almost all suggestions made at the level of oral and written presentations.

We could see security and enthusiasm in presentations perhaps due to the results achieved. In the written deliveries was observed compliance in the style guidelines provided and the use of figures, text and equations themselves.

With regard to prototype design, students get graphic designs from the appropriate expression. On the experimental cycle, reinforcing the theory of experimental error and graphical analysis, of entry could be noted that their analyses have some errors, but they managed to overcome these shortcomings and made a good presentation on their projects. At the level of the feedback we consider that students could actively participate in Workshop III, in this stage of the evaluation it was concluded that students have a good use of the word processor, spreadsheet, and presentation program and design.

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