Quantitative analysis to the teaching of the rotational dynamics (Hypothesis test and survey)

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Carlos Andrés Collazos Morales[1,2,3], **César Mora**[3]
[1] *Physical Laboratory, Manuela Beltrán University, Avenida Circunvalar No. 60-00, Bogotá D. C., Colombia.*
[2] *Colombian School of Engineering, Ak. 45 No. 205-59, Autopista Norte, Bogotá D. C., Colombia.*
[3] *Center of Research in Applied Science and Advanced Technology of National Polytechnic Institute, Av. Legaria 694, Col. Irrigación, C. P. 11500, México D. F.*

E-mail: cacollazos@gmail.com

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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 mechanical for engineering students of two universities in Colombia (Manuela Beltrán University (MBU) and Colombian School of Engineering (CSE)) in 2010. The strategy focuses on three topics of Rotational Dynamics Teaching (RDT) specifically at centripetal force, Inertia moment and theorem de parallel axes and angular momentum conservation. Learning strategies were focused so that students build low cost prototypes let them to use the physical modeling, error theory and graphics analysis around the three topics mentioned. The strategy stimulate and increases the rotational dynamics learning and other learnings (graphical expression, oral and written expression). This research provides the theoretical framework which is based on active work and collaborative learning of the students. Likewise, the methodology described the analysis tools in depth that were used for the data collection process. We present qualitative analysis with hypothesis test (contrast for difference of means), besides of interviews applied to students. The paper presents strengths and difficulties of the strategy employed.

Keywords: Rotational dynamics, construction of prototypes, projects based learning.

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 mecánica para estudiantes de ingeniería de dos universidades en Colombia (Universidad Manuela Beltrán (UMB) y la Escuela Colombiana de Ingeniería (ECI)) en 2010. La estrategia se enfoca en tres temáticas de enseñanza de La Dinámica Rotacional (LDR) específicamente a nivel de fuerza centrípeta, momento de inercia y teorema de ejes paralelos y conservación de momento angular. Se diseñaron estrategias de aprendizaje enfocadas para que los estudiantes construyeran prototipos de bajo costo que les permitirán involucrar el modelamiento físico, teoría de error y el análisis gráfico entorno a las tres temáticas planteadas. La estrategia empleada estimula y aumenta el aprendizaje de la dinámica rotacional y otros aprendizajes (expresión grafica, expresión oral y escrita). Esta investigación establece el marco teórico el cual es fundamentado en el trabajo activo y el aprendizaje colaborativo. De igual forma se describe la metodología empleada ahondando en los instrumentos de análisis que se emplearon para el proceso de obtención de datos y análisis cuantitativos con pruebas de hipótesis (contraste por diferencia de medidas), además de entrevistas aplicadas a los estudiantes. El trabajo presenta las fortalezas y dificultades de la estrategia empleada.

Palabras clave: Dinámica rotacional, construcción de prototipos, aprendizaje basado en proyectos.

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I. INTRODUCTION

The programs in science and engineering use 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 Kelly [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 aplication of the "scientific method" [2].

This research presents the results obtained in the design and construction of prototypes for centripetal force (P1), Moment of Inertia and Parallel Axis Theorem (P2) and

Conservation of Angular Momentum based on our experience in 2010 with student's proyects 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 the rotational dynamics. Section IV we show the methodology used. Section V we present the results. Section VI we present the conclusions of the strategy employed.

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 Ausebel and Piaget [3, 4, 5].

A. Elements

The basic elements according to [6, 7] 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 [6, 7] are:

a) To increase social and communication skills.

b) To allow students to use their individual and collective strengths through collaborative work.

C. Structure

We present a basic structure according to [6, 7].

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 [6, 7].

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 ROTATIONAL DYNAMICS

A. What is?

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

B. Antecedents

University of Maryland has a selection of prototypes for rotational dynamics of the American Journal Physics and The Physics Teacher in section according to [8]. In Latin America, Latin American Journal Physics Education include papers of prototypes for rotational dynamics as in [9, 10, 11].

C. 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.

D. Cycle of experimentation with prototypes

We show the main aspects of the procedure.

a) To generate an experimental work about questions.

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 channels 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.

IV. METHODOLOGY

A. Objective

Measure and assess how The Construction of Prototypes (TCP) and project-based learning (PrBL) increase efficiency in rotational dynamics teaching (RDT), this, at a course in mechanical 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 Question

Does the (PrBL) and (TCP) contribute more meaningfully in the (RDT) at the mechanics course for engineers?

D. Hypothesis

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

E. Pedagogical strategy

The students developed three projects, (P1), (P2), (P3). The strategy is based on bi-weekly 2-hour activities. The project begins with an introduction of the strategy in the first week of classes from the class of theory. For this instance are defined sub-groups (3 students) and the respective topic. In the first week the students know the basic rules under which they will define, execute and present projects. In week 3 students took 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 systems using data acquisition and /or timer low cost. At week 10, were delivered 1 forward written and 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, 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 written in scientific format. These two activities determine the evaluation 3 (Eva-3). The material of Pedagogical strategy is available in [12].

F. Evaluation

The evaluation project is structured in:

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 result of the evaluation for projects is 30% of the course Physics (Mechanics) for students in engineering programs at both universities.

G. Population

The pedagogical strategy (PrBL) and (TCP) in the (RDT) was applied to 8 groups (experimental group) where 4 groups (156 students) belong to the (MBU) and 4 groups (144 students) belong to the (CSE). Each group makes up approximately 40 students. Subgroups were formed later with 3 students and exceptionally 4 students. In the case of (MBU) 52 subgroups were consolidated, in the case of (CSE) were formed 48 subgroups. Additionally there were 8 groups to which were applied traditional instruction (TI) (Control Group).

V. QUALITATIVE RESULTS

A. Theoretical Fundaments (Test for the Difference Between Two Means)

To make a decision about population is important to realize hypotheses [13]. These hypotheses is null (H_0) if the only purpose is to reject them, and alternative (H_1) if it differs from a given hypothesis. A Type I error occurs when the researcher rejects a null hypothesis when it is true. A Type II error occurs when the researcher fails to reject a null hypothesis that is false. A test of a statistical hypothesis, where the region of rejection is on both sides of the sampling distribution, is called a two-tailed test. Table I presents the critical values *z*, confidence level and signification level for two-tailed test.

TABLE I. Critical values *z* for two-tailed test.

Critical values z	-1.645 and 1.645	-1.96 and 1.96	-2.58 and 2.58	-2.81 and 2.81	-3.08 and 3.08
Confidence Level 100(1-p)	90%	95%	99%	99.50%	99.80%
Signification Level p	0.1	0.05	0.01	0.005	0.002

For large samples (N>30) of sizes N_1 and N_2 with respective means μ_1 and μ_2. With standard deviations σ_1 and σ_2. Considering the null hypothesis H_O of no difference between the means, $H_o : \mu_1 = \mu_2$.

The sampling distribution of mean difference is normally distributed with critical value *z* given by Eq. (11). In this way we constrast hypothesis with significance level appropriate.

$$z = \frac{\mu_1 - \mu_2}{\sqrt{\frac{\sigma_1^2}{N_1} + \frac{\sigma_2^2}{N_2}}}. \quad (1)$$

B. Experimental data with project evaluation (Eva-1), (Eva-2), (Eva-3)

Assuming that the difference between the means follows a normal distribution in the case of project evaluation was conducted by difference between means, μ_1, μ_2, μ_3, of each samples, (Eva-1), (Eva-2), (Eva-3). Although samples have different characteristics, the evaluation criteria [25] were the same when we expected to find significant differences between each of the evaluations. This method was applied in three projects: (P1), P2), (P3). Differences between means were performed separately for each university, (MBU) and (SCE). The method used here involves the use of two-tailed test and Type II error. The null and alternative hypotheses were established for 3 cases as is showed in Table II.

TABLE II. Cases of hypotheses.

Case 1)	Case 2)	Case 3)
$H_o : \mu_1 = \mu_2$,	$H_o : \mu_2 = \mu_3$,	$H_O : \mu_1 = \mu_3$,
$H_1 : \mu_1 \neq \mu_2$,	$H_1 : \mu_2 \neq \mu_3$,	$H_1 : \mu_1 \neq \mu_3$,

Tables III, IV and V present the descriptive statistics and z critical values for the three projects in case 1), case 2) and case 3). Using Table IV at the bottom of each table it shows the significance level of p, which indicates the margin of error of the data statistically.

TABLE III. Difference between Two Means, (P1): Centripetal Force in (MBU) and (CSE).

(P1)	Descriptive Statistics			Critical value, z		
	Eva	μ	σ	Eva-1	Eva-2	Eva-3
(MBU) (N=52)	Eva-1	52.73	8.57	-	-11.36*	-17.01*
	Eva-2	71.10	7.91	11.36*	-	-5.86*
	Eva-3	80.17	7.87	17.01*	5.86*	-
(CSE) (N=48)	Eva-1	56.04	8.80	-	-10.81*	-20.91*
	Eva-2	74.67	8.07	10.81*	-	-9.76*
	Eva-3	89.46	6.72	20.91*	9.76*	-

$p^{*}<0.002;\ p^{**}<0.005;\ p^{***}<0.01;\ p^{****}<0.05;\ p^{*****}<0.1$

Based on Table II and III for the case 3) we obtained in the (MBU), a highly significant change between evaluations, (Eva-1) and (Eva-3), at confidence level >99.98% (p <0.002, z = 17.01). For (CSE), we obtained a highly significant change between evaluations, (Eva-1) and (Eva-3), at confidence level >99.98% (p <0.002, z = 20.91).

TABLE IV. Difference between Two Means, (P2): Inertia Moment and Parallel Axis Theorem in (MBU) and (CSE).

(P2)	Descriptive Statistics			Critical value, z		
	Eva	μ	σ	Eva-1	Eva-2	Eva-3
(MBU) (N=52)	Eva-1	55.58	7.77	-	-10.55*	-17.87*
	Eva-2	70.92	7.05	10.55*	-	-7.19*
	Eva-3	80.35	6.29	17.87*	7.19*	-
(CSE) (N=48)	Eva-1	50.85	7.67	-	-14.16*	-27.78
	Eva-2	73.98	8.32	14.16*	-	-11.07*
	Eva-3	90.67	6.31	27.78*	11.07*	-

$p^{*}<0.002;\ p^{**}<0.005;\ p^{***}<0.01;\ p^{****}<0.05;\ p^{*****}<0.1$

Based on Table II and IV for the case 3) we obtained in the (MBU), a highly significant change between evaluations, (Eva-1) and (Eva-3), at confidence level >99.98% (p<0.002, z =17.87). For (CSE), we obtained a highly significant change between evaluations, (Eva-1) and (Eva-3), at confidence level >99.98% (p<0.002, z =27.78).

TABLE V. Difference between Two Means, (P3): Angular Momentum Conservation in (MBU) and (CSE).

(P3)	Descriptive Statistics			Critical value, z		
	Eva	μ	σ	Eva-1	Eva-2	Eva-3
(MBU) (N=52)	Eva-1	52.85	7.87	-	-10.83*	-18.55*
	Eva-2	69.58	7.88	10.83*	-	-7.22*
	Eva-3	80.25	7.18	18.55*	7.22*	-
(CSE) (N=48)	Eva-1	51.10	7.46	-	-14.61*	-24.81*
	Eva-2	74.73	8.36	14.61*	-	-7.92*
	Eva-3	86.96	6.68	24.81*	7.92*	-

$p^{*}<0,002;\ p^{**}<0,005;\ p^{***}<0,01;\ p^{****}<0,05;\ p^{*****}<0.1$

Based on Table II and V for the case 3) we obtained in the (MBU) a highly significant change between evaluations, (Eva-1) and (Eva-3), at confidence level > 99.98% (p <0.002, z = 18.55). For (CSE), we obtained a highly significant change between evaluations, (Eva-1) and (Eva-3), at confidence level> 99.98% (p <0.002, z = 24.81).

C. Survey

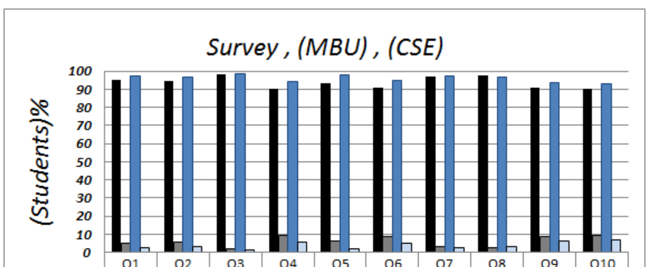
To complement the quantitative analysis was conducted a survey (survey monkey) so which is available in [14]. The numbers of students for (MBU) are 78 and for (CSE) are 144. The questions are:

Q1. Do you believe that the project-based learning and the construction of prototypes are a methodology for the mechanics course?

Q2. Do you think that the topics of the projects were presented in a concise way, on theoretical and

experimental?
Q3. Do you believe that the projects were oriented properly?
Q4. Do you consider that the project helped to understand concepts at the level of rotational dynamics?
Q5. Do you think that the projects established a relationship with other courses like math, graphic and oral expression and written?
Q6. Do you believe that with the projects allowed them the active participation during the course?
Q7. Do you consider that the project creates an environment of mutual collaboration between student and teachers?
Q8. Do you believe that group advances both oral and written to allow continuous feedback during the project?
P9. Do you consider that the cycle (prediction-observation-Validation) with prototypes allows you to understand the topics of the projects?
Q10. Do you believe that the development of projects allows you to correct misconceptions about rotational dynamics?

The Fig. 1 shows the percentage of affirmative and negative answers in (MBU) and (SCE).



	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
yes-MBU	94,87	94,23	98,08	90,38	93,59	91,03	96,79	97,44	91,03	90,38
no-MBU	5,13	5,77	1,92	9,62	6,41	8,97	3,21	2,56	8,97	9,62
yes-CSE	97,22	96,53	98,61	94,44	97,92	95,14	97,22	96,53	93,75	93,06
no-CSE	2,78	3,47	1,39	5,56	2,08	4,86	2,78	3,47	6,25	6,94

FIGURE 1. Survey for (MBU) and (CSE).

Based on the results of the survey we deduce the degree of acceptance that has the methodology in the students.

D. Quantitative Analysis Results

Finishing the projects (P1), (P2), (P3), based on the results observed in (MBU) and (SCE), it 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 presentacions perhaps due to the results achieved. To deliver written 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 desing. Also they have good management system for data acquisition and low cost timer.

VI. CONCLUSIONS

Based on the results (Section VI) shows significant changes between evaluations made before and after applying the teaching strategy on students. The changes were statistically measured and correspond to a level of confidence (>99.98%, p<0.002) for (MBU) and (SCE) in the three projects. In this way, we answer the research question posed in Section IV, on which the (PrBL) and (TCP) contribute significantly in the (RDT).

For the three projects (P1), (P2), (P3) and for two universities (MBU) and (SCE). In this way, we state that students: Worked actively and collaboratively in the implementation of projects. Could establish a process for testing (prediction, observation, validation) with the prototypes developed. (Although the study of cinematic curves generates in them at first difficulty and confusion).

Recognized variables and constants in the physical models involved in the prototypes. Used in a manner acceptable error theory and graphical analysis. Showed that the oral and written presentations and design and construction of the prototype are of great importance because this prepares them in their daily work as engineering students.

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