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# Integrative project: a luxury to achieve knowledge based on wind-power prototype

## Proyecto integrador: Un lujo para alcanzar el conocimiento basado en un prototipo de energía eólica

MACÍAS, Bryan [1]
RODRÍGUEZ, Mateo[2]
MORENO Jiménez, Gustavo Adolfo[3]
BUSTAMANTE Villagómez, Diego Fernando[4]
MOLINA OSEJOS, Jaime Vinicio[5]
MARTÍNEZ-GÓMEZ, Javier[6]
SANCHEZ, Maritza [7]

**Abstract**
The work seeks to determine the effectiveness of the knowledge integrative project as a learning method by evaluating the experience of the project "Construction of a Wind Turbine" to establish whether the incursion into this methodology is positive for the training of students. The rubric and surveys were used to evaluate the results. This method is considered effective for the training of the students because it allowed to reach the learning achievements of the participating subjects.
**Key words:** generator, energy, integrative project, investigation

**Resumen**
El trabajo busca determinar la eficacia del proyecto integrador de saberes como método de aprendizaje mediante la evaluación de la experiencia del proyecto “Construcción de un Aerogenerador Eólico” para establecer si la incursión en esta metodología es positiva para la formación de los estudiantes. Se utilizó la rúbrica y encuestas para la valoración de los resultados. Este método se considera eficaz para la formación de los estudiantes porque permitió alcanzar los logros de aprendizaje de las materias participantes.
**Palabras clave:** generador, energía, proyecto integrador, investigación

[1] Automotive Mechanical Engineering Undergraduate Student, Universidad Internacional SEK – Quito, e-mail: bmacias.mec@uisek.edu.ec
[2] Automotive Mechanical Engineering Undergraduate Student, Universidad Internacional SEK – Quito, e-mail: mrodriguez.mec@uisek.edu.ec
[3] Master of Science Technology Management Gustavo Moreno, Academic staff, Universidad Internacional SEK – Quito. e-mail: gustavo.moreno@uisek.edu.ec
[4] Master of Mechanic Designee Diego Bustamante, Academic staff, Universidad Internacional SEK – Quito. e-mail: diego.bustamante@uisek.edu.ec
[5] Master of Mechanic Designee Jaime molina, Academic staff, Universidad Internacional SEK – Quito. e-mail: jaime.molina@uisek.edu.ec
[6] PhD in Material Science and Engineering Javier Martínez-Gómez, Academic staff, Universidad Internacional SEK – Quito. Research at Instituto de Investigación Geológico y Energético (IIGE), Quito, Ecuador. e-mail: javier.martinez@uisek.edu.ec
[7] Research Group YASUNI-SDC, Escuela Superior Politécnica de Chimborazo, Sede Orellana, El Coca EC220001, Ecuador, e-mail: maritzac.sanchez@espoch.edu.ec

## 1. Introduction

With a society in constant change, Higher Education Institutions (HEI) deal with the challenge to form professionals with the capacity to face social, economic, scientific and technological changes (Beneitone et al., 2007; Villacreses et al., 2017), but above all with the power of problem solving situations accompanied by a professionally ethic and socially responsible performance (Benatuil & Laurito, 2014; Martínez-Gómez et al. 2018).

In Ecuador, HEI have suffered several modifications among the past years due to social, scientific and technologic changes and environmental demands(Godoy et al. 2017; Rojas et al., 2008). For example, employers demand professionals with high level skills that respond to the needs of the different productive sectors, which promote the generation of pedagogic and didactic strategies that prove the knowledge of products and services of each sector (Acurio et al. 2019; Aldas et al. 2019; Beltran et al. 2019). As well as, curricular programs where the dominant notions are: academy, social or technological efficiency, personal fulfillment, social construction, practical perspectives and innovation in order to evade the formation of professionals who later become unemployed with high academic standards (Murillo, et al.,(2016; Villacreses et al., (2017).

Increasing the relevance of education programs in relation to professional demand, managing the quality of learning processes through performance evaluation and developing an international educational policy (Acurio et al. 2018); (Espinoza et al. 2018). That contributes to contemporary research are the aspects in which the importance of the higher education model by competences aims, which has a holistic approach that emphasizes the constructive development of skills, knowledge and attitudes that allow students to properly insert themselves into the work structure and adapt to social changes and demands (García, 2011); (Villacis et al., 2015)

One of the methodologies applied in the competency education model is Problem-Based Learning which focuses on research and critical thinking to solve a problem (LLanes et al., 2018; Gaona et al. 2017). At that instance students become the protagonists of learning and teachers in charge serve as mediators of this methodology (Rivero, Murillo, & Ferrer, 2017; Villacreses et al., 2019). A research made by (Moreno et al. (2019); Kastillo et al; (2015) who use the method of evaluation through Knowledge Integrative Projects has demonstrated acceptance from the point of view of soft skills by students who have undergone this model of education obtaining a positive effect on their performance in relation to their leadership and decision making. The Knowledge Integrative Project based on Problem-Based Learning is a method that promotes creativity and critical thinking, turning the student into a self-taught learner who works cooperatively to understand the theoretical lessons (Ding, 2016; Chingo et al. 2020)

For the implementation of the Knowledge Integrative Project the teacher presents a problem related to the Integrative Chair of the study level, organizes the work teams and establishes the guidelines, the students analyze the problem and identify the learning needs to solve it to start the process of research, which involves review of bibliographic references, experimentation, systematization of data, analysis of results, proposal of possible solutions and socialization between the student and teacher community to obtain feedback (Merino, et al (2019); (Martínez-Gómez et al. 2017). This allows to obtain skills such as: problem solving, decision making, teamwork, communication, argumentation and delivery of information, as well as attitudes and values: thoroughness, precision, review, tolerance, contrast (De Miguel Díaz, 2005; Martínez et al. 2017). In this way, the methodology used by the Knowledge Integrative Projects becomes a cognitive, emotional and psychological potential. Involving a comprehensive synergy in the training of students thus ensuring a development in individual and collective skills.

In this context, the objective of the given paper is to determine the effectiveness of the Integrative Project of Knowledge as a means of learning through the evaluation of experience acquired inside the career of Automotive

Mechanical Engineering, by the construction of a Wind Power Generator, which will guarantee the quality of education and professionals that the university is providing and at the same time recommend enhancements during its application.

# 2. Methodology

## 2.1. Formulation of the knowledge integrative project

A meeting is held in which the representatives of each level of the career must be present and, in conjunction with the faculty coordinator, 3 possible innovative projects are proposed. The project that meets the expectations of students and teachers is selected. Before applying for each project, it must be considered:

- The technological scope must be subject to what may be available depending on the location where the integrative project will be used.
- Degree of difficulty must be in accordance with the academic level in which the project is focusing and with the subjects in which each of the elements can be integrated so that it is feasible to carry it out.
- Budget

By taking into account these parameters, prior to approval, will allow the project to be directed towards a comprehensive development helping students to provide an answer to a problem through a prototype. The current project was based on the development of a wind turbine that enables natural energy to be converted into electrical energy. The type, design and size will be subject to students' choice. However, the objective of this task will be to produce 1W of power through the enameled wire coils.

## 2.2. Design of the learning process through the construction of the *Wind Power Generator*

The design, planning, organization and experimentation of the Construction of a ***Wind Power Generator***, as an integrated project of knowledge of the third level of the Mechanical Engineering career of the Faculty of Architecture and Engineering of the Universidad Internacional SEK included the participation of five subjects, through which the activities described in Table 1 were carried out.

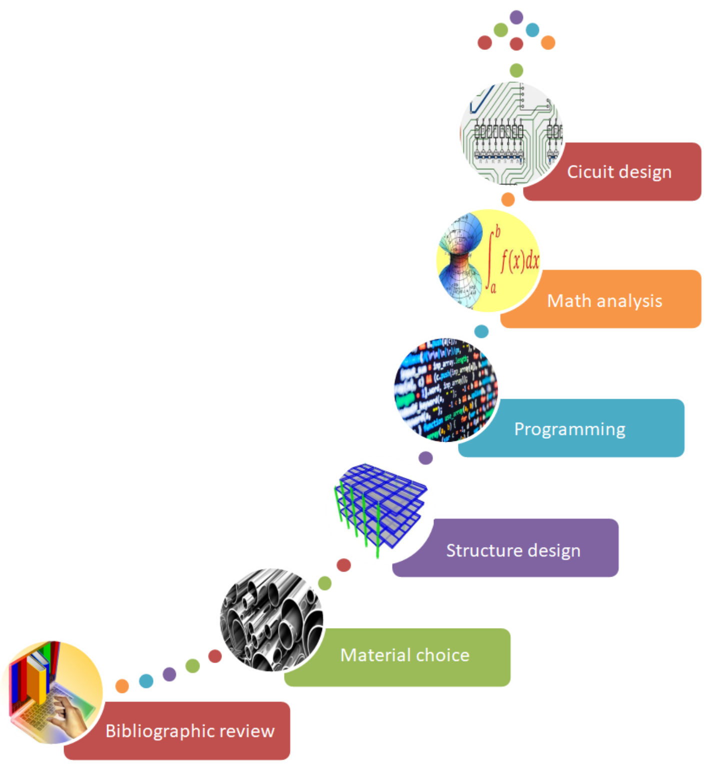
**Table I**
Subjects corresponding to the development of the integrative project
of knowledge ***"Construction of a Wind Power Generator"***

| Subjects | Learning activities | Expected learning outcomes |
|---|---|---|
| Statics | Design of structures with stress simulations. CAD software *Autodesk Inventor* was implemented for those simulations | Evaluate the results of stresses and mechanical strains through the implementation of load analysis methodologies applied in structures. |
| Material Science | Study of Stainless Steel 304 properties, fiberglass as a cast for the coils and phosphatized covering found in the shaft and the holding plate of the structure of the wind power generator | Identify the relationship between the structure and the physical properties of the materials used for its construction by means of techniques of characterization of materials in function of its engineering application |
| Programming | Elaboration of a program with Arduino able to obtain the voltage, current and turning speed data. A voltage divider and an Encoder sensor were used | Design computational programs through programming techniques oriented to objects for the automation and problem solving applied to engineering |
| Math Analysis III | Use of an empirical math model based on the obtainment of the energy produced by the generator based on the air intake speed. | Analyzes the different analytical methods of integration through the application of math modeling for problem solving applied to engineering |

| Subjects | Learning activities | Expected learning outcomes |
|---|---|---|
| | Microsoft Excel software was implemented to interpret the behavior of such variables | |
| Electrical Engineering | Analysis of the wave produced by the generator and calculation of the power generated in order to know the behavior of the device and interpret the changes it suffers from increasing or decreasing the intensity of the wind or such variables. | Design electric circuits and machines by the application of different methods of analysis and problem solving with math models in order to control the electricity for different purposes in engineering. |

The overall process of the project and its main events planned are illustrated in the Figure.1. In each phase, students performed specific tasks to produce the prototype.

**Figure 1**
Scheme of the experimental phases of the project
***"Construction of a Wind Power Generator"***




**Bibliographic review**

Students reviewed at least 18 bibliographic sources from which the prototype developed was based on the model given by B. Wahyudi, 2013, who promotes the integration of clean energy technologies

**Material choice**

It consisted in determining the optimal material for the construction of the blades of the generator. A Scanning Electrical Microscope SEM of model DSM-960A was used, from which tests in steel 304 were carried out. This allowed to identify the structural characteristics of such material.

**Structure design**

For the design and simulation of the structure some parameters were taken into account such as load and moments analysis in order to determine the capability of the structure to resist adverse loads under any circumstance.

A free body diagram was made, where all the loads that impact the integrity of the structure are shown, then a static analysis will be made. It was also determined the load that the wind exerts on the critical points and for such reason the given equation found on (WikiHow, 2019) and (Fullmecanica, 2014) will be implemented.

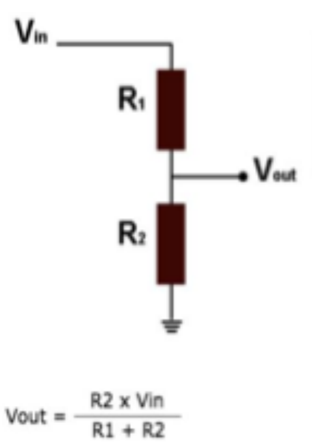
$$Fv = A * 0{,}613V^2 * Cd \qquad [1]$$

**Where:**
**A:** Area of pressure of the wind
**V:** Wind speed
**Cd:** Thrust coefficient (0.8 for small tubes and 1.2 for large ones)

**Programming**

To obtain the speed of rotation, an Encoder sensor was used to obtain a signal when there was a movement. With this information and through the voltage divider equation, the frequency and the number of revolutions per minute were obtained. For the current and voltage, the voltage divider method was used, which consists of placing two resistors in series to obtain the input voltage as shown in Figure 2.

**Figure 2**
Scheme and formula for voltage divider




$$Vout = \frac{R2 \times Vin}{R1 + R2}$$

**Where:**
**$V_{out}$:** Output voltage.
**$V_{in}$:** Input voltage.
**$R_1$:** First resistance.
**$R_2$:** Second resistance.

**Math analysis**

An experimental/empirical model was made, which by means of computerized graphics allowed the interpretation of the operation of the wind turbine in a simple way, generating a table that relates the voltage and current intensity formed by means of the variation of resistances until obtaining the value of the Nominal Power, which was calculated with the formula:

$$P = V * I. \quad [2]$$

A table was also generated that related the RPM to the Rated Power at each instant. The RPM and the angular speed are the same magnitudes but with different units, which established a new relationship between the wind generated speed and the angular speed. To obtain the value of the power generated in the rotor, the equation was used:

$$P\,r = 12\,\rho * v^{3} * \pi * r^{2} \quad [3]$$

**Where**:
**ρ:** Dry air density
**v:** Wind speed
**r:** Radius of the rotor circumference. Based on this, build a new table that relates the angular velocity to the power generated by the rotor.

**Circuit design**

For the circuit design, an analysis of the wave produced by the wind turbine was carried out and the value of the power generated was calculated in order to know the behavior of the device and to interpret the changes it undergoes when the wind intensity or other variables increase or decrease.

## 2.3. Evaluation of the pedagogical method

The evaluation of the pedagogical method consisted in knowing the learning results achieved by the students and their perception of the method applied for the execution of the project "Construction of a Wind Power Turbine".

Learning outcomes were measured through the rubric set out in Table 2, which indicates the parameters assessed to each of the students and their qualification.

**Table 2**
Evaluation section of the knowledge integrative project

| Evaluation parameter | Parameter description | Category |
|---|---|---|
| **Mastery of the subject** | Masters the subject with clarity and precision, answers questions, uses examples has capacity for analysis/synthesis/evaluation | 90%-100% Highlighted |
| **Solve the research problem** | The work presents a concrete and precise solution to the research problem posed. | 50%-89% Acceptable |
| **Presentation of the work** | The product fulfills all the functions required to meet the established needs. | <50% Deficient |
| **Innovation** | El producto cumple con todas las funciones que se requierren para satisfacer las necesidades establecidas. | |
| **Quality of bibliographic review** | The selected references are relevant and have been appropriately cited. | |

The students' perception was evaluated by means of surveys with a closed-ended questionnaire to 22 students of the third level of the Mechanical Engineering career. The results were analyzed using the Excel® program (Rodríguez-Sandovall & Cortés-Rodriguez, 2010). Table 3 shows the bank of questions used in the survey.

**Table 3**
Bank of questions asked in the student survey
for the evaluation of the pedagogical method

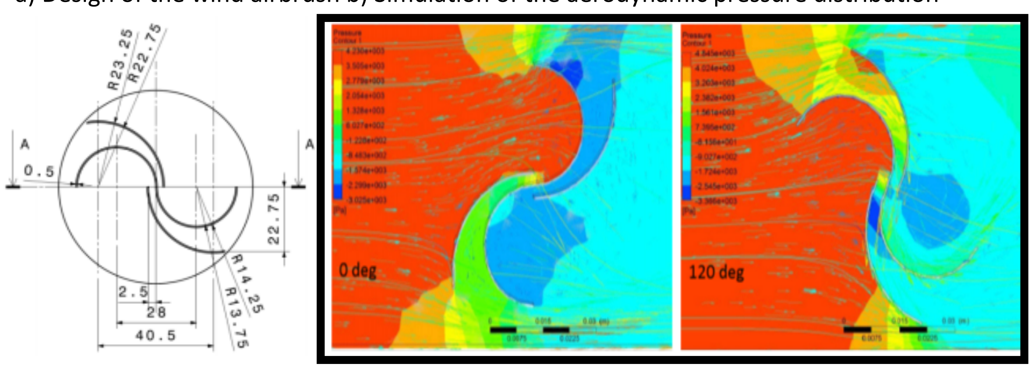
| N° | Question |
|---|---|
| 1 | Do you think that the classroom project is important for your professional training? |
| 2 | Was it difficult to find an appropriate project idea to develop in the course? |
| 3 | Were the concepts seen in class applied to solving the problems of the integrative project? |
| 4 | Do you think the way the project was carried out during the semester was adequate? |
| 5 | Are you satisfied with the way the classroom project was advanced (delivered) during the semester? |
| 6 | Do you consider that the final evaluation of the project corresponds to 40% of the final exam grade in each subject? |
| 7 | Is the time stipulated for the experimental development of the project sufficient? |
| 8 | Do these types of learning methodologies satisfy your expectations as a student compared to other traditional methods? |
| 9 | Do you agree that the winner of the engineering week is exempted from the final exam in the subjects relevant to the integrating project? |
| 10 | Do you think that the orientation for the development of the work by the teacher met your expectations? |

## 3. Results

### 3.1. Learning experience

Experimental learning began with a review of the literature, from which the design of the Wind Power Generator was obtained as shown in Figure 3a, this was subjected to a computer simulation as shown in Figure 3b

**Figure 3**
a) Design of the wind airbrush b) Simulation of the aerodynamic pressure distribution




**a)** **b)**

Figure 4 shows a microscopic image of steel 304, which illustrates the processability, weldability and corrosion resistance properties of this material used for the construction of wind Power Generator Blades.

**Figure 4**
Microscopic image of steel 304

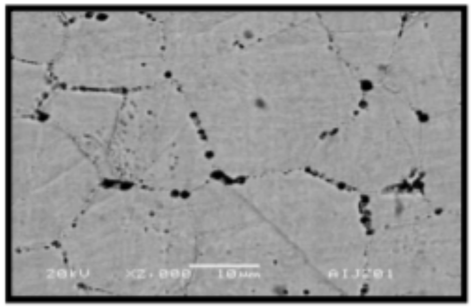


Fig.2.1 Micrografía de Acero sensibilizado
2000X

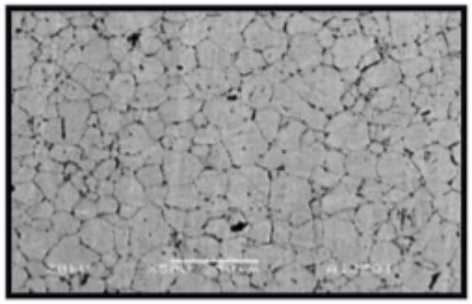


Fig.2.2 Micrografía de Acero sensibilizado
500X

In the selected free body diagram, the loads were applied at the critical points as shown in Figure 5 and the maximum stress that the support can resist before deformation was determined.

By comparing the results in Table 4 with those shown in Figure 5a, it was found that most sections did not have any applied loads. However, minimal deformations did exist, suggesting that the structure is capable of withstanding possible wind loads. Additionally, it can be stated that the structure is incapable of deforming or breaking due to its safety coefficient of 15, which corresponds to the maximum resistance coefficient. The design of the support, therefore, resisted the weight of the generator and the different wind flows.

**Figure 5**
a) Free body diagram. b) Inventor simulation

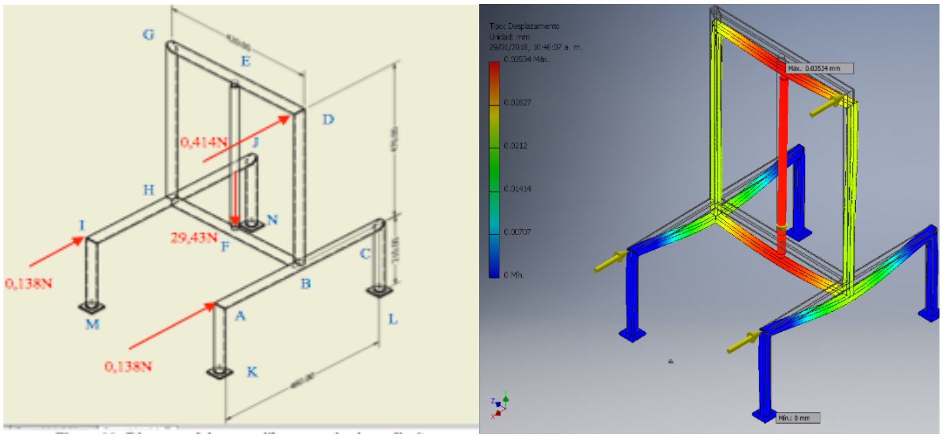


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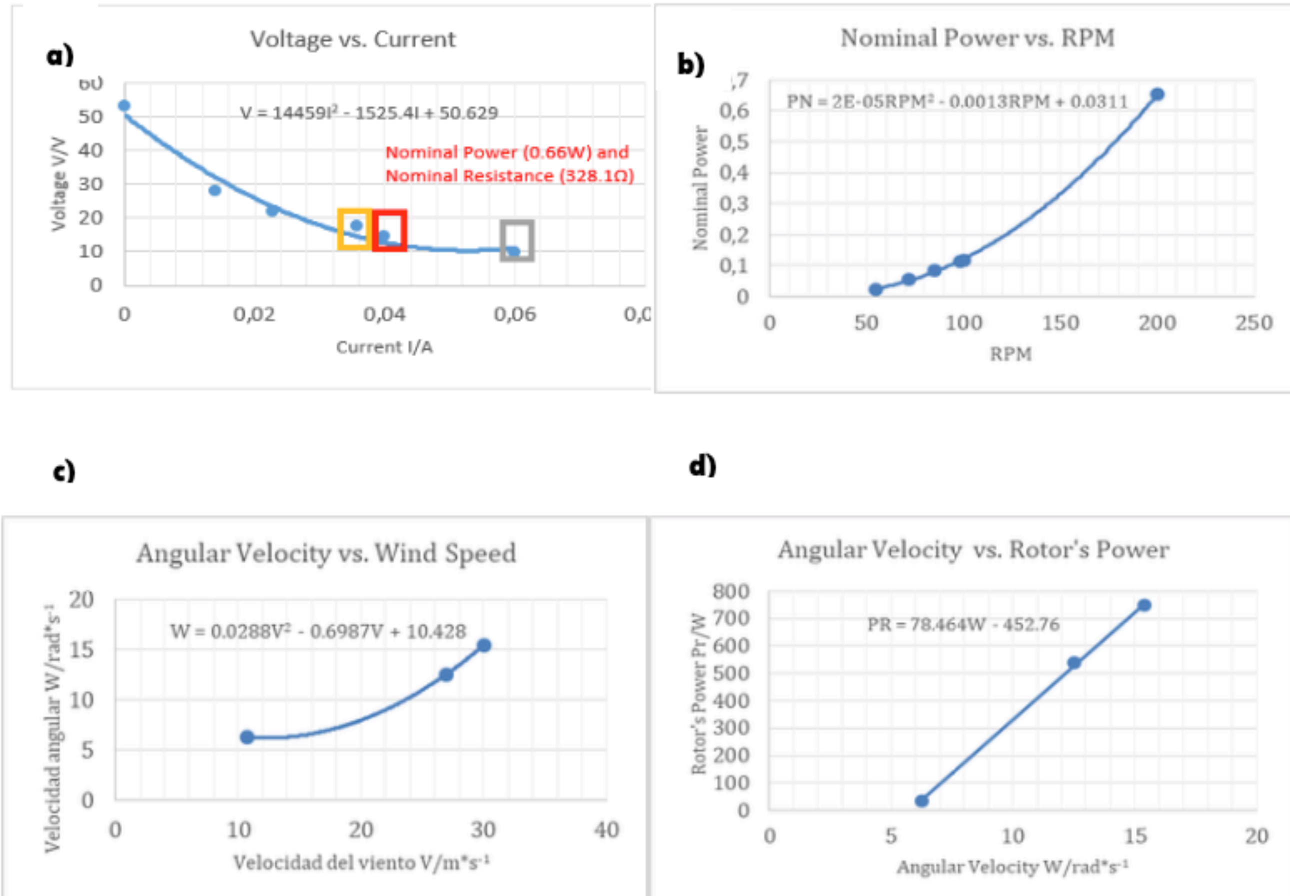
**Table 4**
Forces and Moments obtained in each node

| Node | Loads and moments |
|---|---|
| **A** | $F_{AK}$= 0N |
| | $F_{AB}$= 0,138N (C) |
| **B** | $F_{BD}$= 0N |
| | $F_{BC}$= 0,138N (C) |
| | $F_{BF}$= 0N |
| **C** | $F_{CL}$= 0N |
| **D** | $F_{DE}$= 0N |
| **E** | $F_{ED}$= $F_{EG}$ =0N |
| | $M_E$= 0.0869 N.m |
| **F** | $F_{FE}$=29,43N (T) |
| | $F_{FB}$= FFH =0N |
| **G** | $F_{GH}$= 0N |
| **H** | $F_{HI}$= FHJ |
| **I** | $F_{HI}$=0,138N (C) |
| | $F_{IM}$= 0N |
| **J** | $F_{JN}$= 0N |

In the programming process, the Arduino board allowed to obtain real values of the voltage, current and revolutions per minute of the Wind Power Generator without the need to measure with a multimeter or other device. This allowed to have an automated measurement system to know the status of the generator in real time, as well as determined the highest voltage peaks as a function of wind speed.

The development of the mathematical model sought to define the behavior of the wind generator with respect to the wind. The method used was empirical trial and error, obtaining the graphs presented in Figure 6.

**Figure 6**
Relationship between a) Voltage vs. Current, b) Nominal Power vs. RPM,
c) Angular Velocity vs. Wind Speed and d) Angular Velocity vs. Rotor's Power



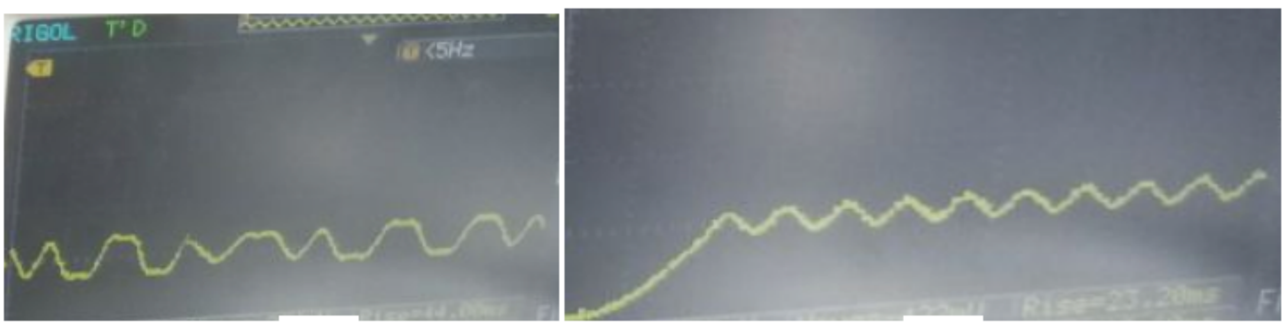

In the figure. 6a indicates that the nominal power obtained was 0.66W with a nominal resistance of 328Ω. Figure 6b shows that as rotor RPM increased, the power rating increased, and was adjusted to a second order polynomial ratio. Similarly, the relationship between wind input speed and angular speed generated in the rotor shown in Figure 6c shows a second order polynomial proportionality relationship. Figure 6d shows the direct proportionality relationship between the angular velocity generated by the wind and the power in the rotor.

By using electromagnetic theory to generate energy through coils and magnets, a prototype wind generator was designed and built, obtaining 1.16W of clean energy. Figure 7 shows the elaboration of the prototype that the students of the third level of Mechanical Engineering made.

**Figure 7**
"Savonius" Wind Power Generator

During the circuit design work, a waveform was generated in the oscilloscope that was not completely sinusoidal because it had double positive peak sections due to the use of an odd number of magnets. This means that in some of its sections, two equal poles are interacting as shown in Figure 8a.

**Figure 8**
**a)** Unrectified wave of the parallel connection
**b)** Rectified wave of the parallel connection



**a)** **b)**

In Figure 8b, the waves are rectified by the diode bridge, which aims to convert the AC wave into DC by converting its negative peaks into positive ones.

According to Table 5, the connection with higher power can be obtained in series because it consumes less amperage and generates higher voltage, while the parallel connection produces less power but consumes more amperage. Therefore, the series connection is chosen for the construction of the wind turbine because it has coils of very low thickness enameled cable, so it cannot occupy a high amperage to prevent the coils from burning.

**Table 5**
Power obtained from Serial and Parallel connections.

| Connection type | Power |
|---|---|
| Series | 1.16 W |
| Parallel | 0.67W |

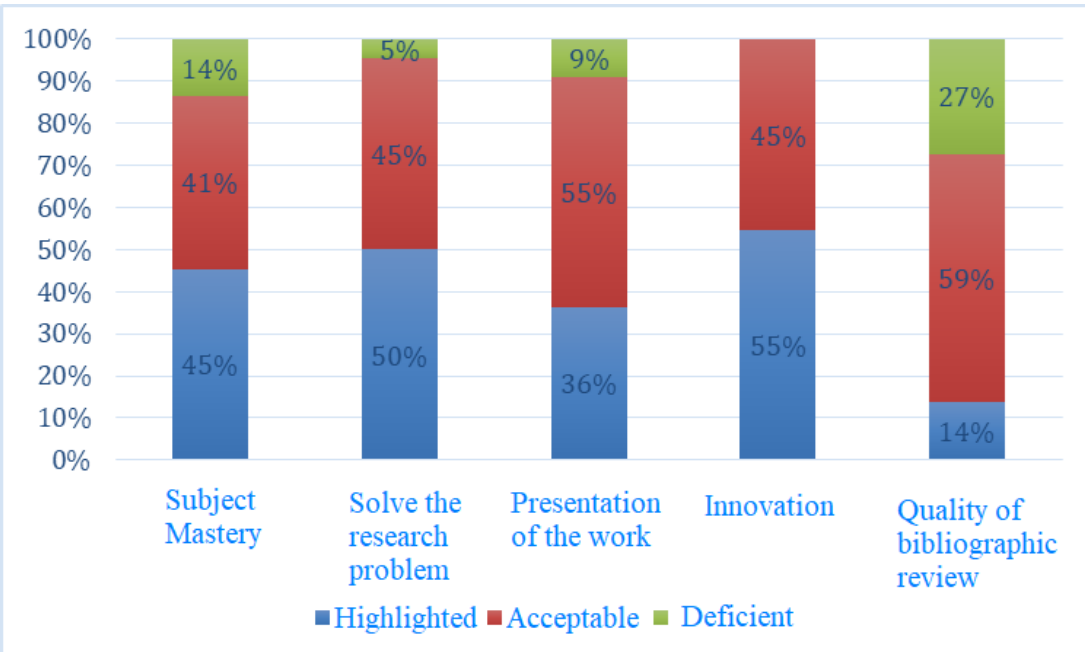
## 3.2. Evaluation of the teaching method

The evaluation of the pedagogical method presents the compendium of the grades reached by the students at the end of the knowledge integration project and the perception of the methodology for its development.

### 3.2.1. Learning Results

The learning outcomes are presented in Figure 9 , which indicates that about 50% of students developed innovation, and the ability to solve problems and master a specific topic, however it is also clear that it is necessary to strengthen the knowledge and skills to present a work of scientific nature and the search for quality literature.

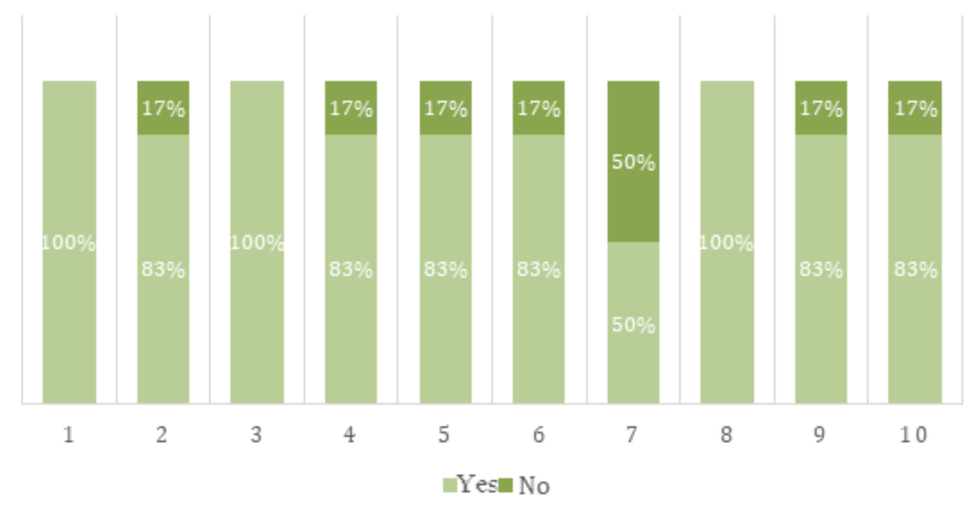
**Figure 9**
Learning outcomes




### 3.2.2. Perception of the learning method

The results of the student surveys to find out their appreciation of the learning method are shown in Figure 10. The positive response of all students to questions one, three and eight, which correspond to the importance of the method, application of course knowledge and preference over other methodologies respectively, shows that the knowledge integrative project is appreciated by the students as a method that will contribute to their training in a positive and practical way.

**Figure 10**
Results of students' perception of the knowledge integration project




The 83% of affirmative answers to question two, which seeks to identify the degree of difficulty that the student had in defining the idea of research, shows that despite the effort that the application of the method demands of the student, he or she values it positively.

Questions four, five and ten, which refer to the way in which the learning method was executed, presented 83% of affirmative answers. This allows us to affirm that the way in which the project was executed and the control of its progress, as well as the guidance given by the teacher, were accepted by the students and according to the students' statements, allowed them to acquire and retain knowledge that would not have been achieved with master classes.

83% of positive responses to questions six and nine, which refer to the students' compliance with the incentives granted for outstanding work, showed that public recognition and assessment by means of merit grades is a significant motivation for developing their learning and research capacity.

## 4. Conclusions

The knowledge integration project "Construction of a Wind Turbine" allowed mainly to develop the problem-solving capacity and to foster innovative ideas in the students, which determines the effectiveness of the method to achieve learning results. This is ratified by the preference of students for this methodology over others, despite the difficulty it represents, due to the application of knowledge it implies.

The experience generated in the construction of the prototype of a Wind Turbine enabled students to obtain clean energy, carry out structural and material evaluations, design a program, analyze analytical integration methods and design circuits, which results in the fulfillment of the learning results established for the third level of a Mechanical Engineer's training.

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