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APPLICATION OF PROBLEM-BASED LEARNING FOR THE DEVELOPMENT OF A CLASSROOM PROJECT IN THE FUNDAMENTALS OF CONTROL AND AUTOMATION COURSE

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Abstract

This article presents the application of the problem-based learning methodology applied in a classroom project, the development of this learning methodology is framed in the social constructivist pedagogical model focusing the generation of new knowledge in the student and placing the teacher as a facilitator.

This methodology starts with the selection of the work group, this was achieved by identifying the learning styles of each student through the Honey - Alonso learning styles identification test, which showed that 40% of the students have a pragmatic learning style, 30% have an active learning style, 20% have a pragmatic learning style, and 20% have an active learning style, and the rest have a pragmatic learning style, This is important when it comes to teamwork, since each member contributes from his or her capacity to acquire knowledge and there is a relationship between the learning style and the leadership and moderation roles required for such work. After organizing the work group, the problem-based methodology was developed, with the correct identification of the problem, going through a brainstorming process and finally proposing a solution.

The solution proposed was the design of a solar photovoltaic plant, and its design is presented as an evaluation method for the development process of the problem-based learning methodology.

Keywords: Problem-based learning, learning styles, renewable energies, solar energy, design.

1. INTRODUCTION

Problem-based learning (PBL) is an active teaching-learning methodology in which a problem is addressed and a solution is proposed. The starting point, therefore, is the posing of a specific problem and the needs for the specific case must be detected (Tay & Noum, 2020).

PBL involves identifying a contextual problem that allows the student to construct his or her own knowledge from the exercise of generating an efficient solution or solutions. With this, there is a substantial change from the traditional memoristic methodology to a new constructivist approach (Cariani, 2022; Dahal et al., 2022; Huerta Ramirez et al., 2018; Paredes-Curin, 2016). This suggests changing the teaching based on lectures and the resolution of typified problems far from the needs of society, for a new active methodology (Ruiz-Meza et al., 2021).

Likewise, classroom projects are presented as a tool for strengthening formative research, since they seek to take advantage of the knowledge gathered in the subjects on a specific process or product, through which the student acquires the ability to relate theoretical concepts with practical experience to solve real problems (Narvaez Caballero & Gélvez García, 2020).

In this same sense, the objective of the course is to generate the appropriation of knowledge related to industrial automation, including instrumentation, and process control for its application in the field of engineering. That is why the application of PBL goes hand in hand with this goal, giving the student the opportunity to be an active part of the solution to real problems.

It is for this reason that in the development of the course, the development of a structured and organized solution in the regional environment, which is related to the course, was proposed as a classroom project. This is how the problem found in the infantry battalion number 15 General Santander lends itself to the application of the strategy.

This document is organized as follows: section 1 presents the introduction, section 2 presents the materials and methods, section 3 presents the PBL methodology used, section 3 presents the results obtained and finally, conclusions are given.

2. Materials and methods

The document deals with the application of a PBL methodology to the development of a classroom project, with a group previously established according to their learning style (L2). Each of the stages of the process are shown below.

- Selection of the working groups.

The selection of working groups is of utmost importance for the application of PBL, as all members are required to contribute ideas and make equal contributions. According to (Cantorin Curty, 2015) there is a relationship between the learning style (LS) and group work, so each group had a student with active LS to lead the group and a student with reflective LS to serve as moderator and mediator.

For the identification of learning styles, the Honey - Alonso learning styles identification test was performed (Freiberg Hoffman & Fernández Liporace, 2013). The results obtained in the working group say that 40% of the students are pragmatic LS, 30% are active LS, 20% are reflective LS and only 10% of the students in the group are theoretical LS as shown in Figure 1.

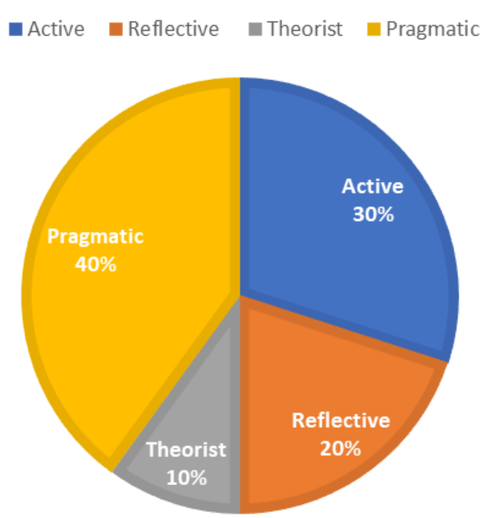

Figure 1. Honey - Alonso learning styles test results.

- Presentation of the problem and clarification of terms

At this stage, the problem or case is presented to the students and they are given time to read and review it carefully, initial doubts are resolved and delivery and completion times are established.

- Problem definition

From this stage on, the teams begin to work and the teacher takes on the role of tutor or guide. To begin with, they should analyze the proposed case and discuss to identify the problem or problems to be solved. They should express it in a single question or statement, and the following was determined by consensus:

How can the heliport landing lights of the Infantry Battalion No 15 General Santander heliport be powered with electric energy?

- Brainstorming.

In this part the problem is finished structuring, the groups must carry out a brainstorming where each student exposes their knowledge about the case, the circumstances surrounding it, what people or things it affects, or what implications it has. Here clear rules are established, the leader directing and the moderator acting as mediator so that there is no debate in this part.

- Proposing answers and hypotheses

Once the problem has been structured, the students should bring up their previous knowledge, acquired in class or by other means, relate ideas, and propose possible answers to the problem. Each student should contribute his or her opinion, and together, they should discuss and evaluate the validity of the knowledge and hypotheses. The teacher serves as a guide and questions the proposals so that the students themselves can discard failed hypotheses and generate adequate answers.

- Formulation of learning objectives

At this stage, concepts and dilemmas arise that the students are unable to solve. It is at this point that learning objectives are formulated. That is, what they do not know, but need to learn to solve the problem. It is also the time both to define the strategies they will use to achieve these learning objectives during the next phase and to organize the investigation.

- Research

This is the time for the students to undertake the search for information to solve the dilemmas that have been emerging, to achieve the learning objectives set, and to delve into the roots and possible solutions to the problem. To obtain the data and knowledge they need, they can consult books, magazines, newspapers and Internet pages, but also interview experts, conduct experiments, make field studies, models and representations, among others.

- Synthesis and presentation

Once the research is completed, students synthesize the information gathered, covering all of the learning objectives, and develop a response to the problem in the previously established format. Dialogue and collaboration are crucial in this phase, finally they will present the solution to the rest of the classmates.

- Evaluation and self-evaluation

This last stage consists of evaluating the students' work using the rubric shared with them at the beginning. A self-evaluation is also performed, this will help them to develop their spirit of self-criticism and reflect on their failures or mistakes. At this stage, the final design of the classroom project is presented with the solution to the problem posed**.**

3. RESULTS

With the results of the test shown in Table 1, a working group was formed and the established roles were assigned

Table 1 LS test results

style	No.	Percentage
Active	3	30%
Refletive	2	20%
Theorist	1	10%
Pragmatic	4	40%
TOTAL	10	100%

The problem was presented as established in section 1, making the problem known, and a brainstorming session was conducted, establishing the most relevant topics related to the generation of renewable energies.

As a result of the brainstorming, a research was conducted in scopus about renewable energies, resulting in figure 2.

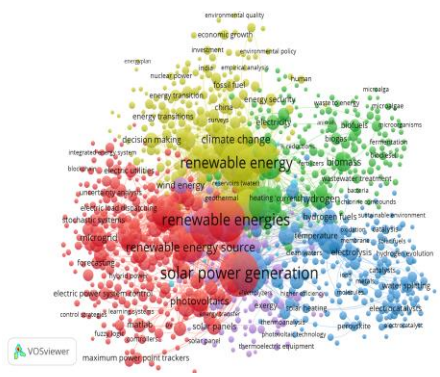

Figure 2. Relationship of occurrence of the subject matter

Figure 3 shows the density of the network of relationships from the number of occurrences, where yellow represents the highest density and blue the lowest concurrence of the renewable energy theme giving a trend of the implementation of solar photovoltaic energy in the literature.

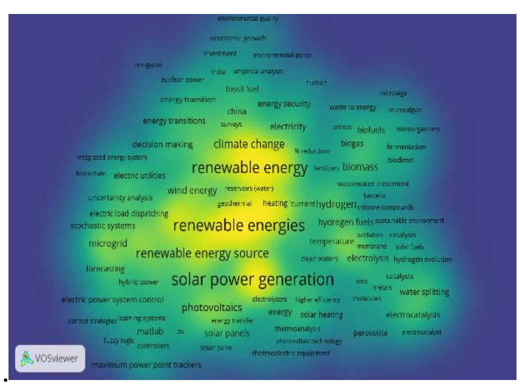

Figure 3. Density of the relationship network of the subject matter

The evaluation process focuses on three aspects, the main one being the evaluation of the student, the evaluation of the teacher and finally the evaluation of the problem. In order to carry out this evaluation, an evaluation rubric was proposed that invokes these three aspects, from the point of view of both the student and the teacher.

The rubric is arranged to indicate from 1 to 4 in the corresponding box, according to the criterion of each evaluator (teacher-student) according to the most appropriate performance for each of the requirements. The performances to be indicated are:

1 Optimal performance

2 Good, but needs some improvement

3 Fair performance

4 The objective is not achieved

Table 2 shows the evaluation rubric addressed to the student, which proposes a self-evaluation and a co-evaluation, assessing the degree of commitment, attitude and interest of the different members of the team.

Table 2 Student-directed assessment

Requirement	**Student's own evaluation**	**Peer evaluation**	**Teacher evaluati on**
Participates with enthusiasm and energy (actively)			
Focuses on the problem			
Does and gives his/her best			
Engages with commitment			
Enjoys the process			
Is the director of his/her own learning process			
Displays collaborative skills with the rest of the participants			
Generates hypotheses through the process			
Generates ideas based on valid arguments			
Accepts feedback from peers and the teacher			
Takes into account its own educational goals			
Reflects on own problem solving (meta-cognition))			
Your learning is self-directed			
Transfers problem-solving skills from the classroom to the real world			
Assumes personal and group responsibility for the learning process			
Continues to generate questions throughout the process			
Increases confidence to work in a team			

Improves active listening skills to other team members	
Demonstrates how much he/she has learned	
Demonstrates a collaborative attitude	
Demonstrates assertive communication skills	
Negotiates to synthesize ideas, make decisions, and resolve disputes within the group	
Shares findings through oral presentations	
Communicates information clearly and concisely in oral presentation	
Uses relevant material in oral presentation	

Table 3 shows the evaluation rubric addressed to the teacher by the students and also proposes a self-evaluation assessing the degree of commitment, attitude and performance of the teacher.

Table 3 Teacher evaluation

Requeriment	**Student's own evaluation**	**Teacher self-evaluation**
Design the problem to satisfy the educational objective		
Designs the problem to promote a higher-order activity		
Takes into account the educational purpose of the problem		
Is an effective facilitator of thinking and learning		
There is cognitive congruence		
Allows the learner to be the center of the learning process		
Avoids giving masterful answers and lectures		

Table 4 shows the evaluation rubric directed to the problem itself by the students and also poses a self-evaluation assessing the degree of commitment, attitude and performance of the student.

Table 4 Evaluation directed to the problem itself

Requeriment	Student evaluation	Teacher evaluation
Is challenging for the student		
Invites the application of the knowledge of the course towards the search for the answer.		
Promotes reflection among students		
Stimulates thinking skills		
Promotes higher level thinking		
Allows students to extend their knowledge base and competencies		
Is meaningful to the learner (within the realm of everyday life and experiences)		
Relates to the student's future professional life plans		
Allows for the pursuit of further analysis of solutions		
Increases student interest in the content being studied		
Creates a sense of community in the classroom		
Motivates self-directed learning		
The solution to the problem posed is relevant to the educational needs of the students.		
Motivates self-directed learning		
Promotes active learning		
Increases academic achievement		
Increases application and retention of information		
Promotes critical thinking		
Promotes implementation of teamwork skills		
Motivates fieldwork for data collection		

As part of the evaluation is the development of the solution to the problem posed, this was proposed as follows: *In the Infantry Battalion No 15 General Santander located in Ocaña Norte de Santander there is a helicopter landing strip, from which operations depart for the entire region of Catatumbo, this landing strip has no lighting or landing lights because it is too far from the power grid, as a result of this night operations can not start or arrive from the battalion*. As an additional condition, the students were told that the solution should be focused on the use of renewable energies.

Finally, as a solution to the problem presented, consensus was reached that the best alternative for powering the heliport landing lights of the 15th General Santander Infantry Battalion is a solar photovoltaic plant. This solar plant must comply with the characteristics and conditions specified initially, that is why its design is presented.

The design of this photovoltaic solar plant is the result of a problem-based learning pedagogical strategy, since this real case is presented and the solution proposed is the development of this article.

The starting point is to know the distribution of the luminaires, for which the scheme (Figure 4) and positioning of the luminaires was made by means of a topographic study and the calculation of each of the components of the solar plant.

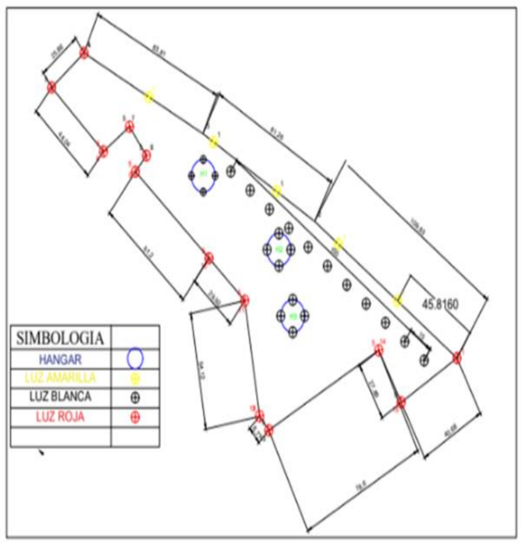

Figure 4. Diagram and positioning of lights.

The following design is developed applying the law number 1715 of 2014 that regulates the use, application and development of alternative energies in Colombia, likewise the technical standards NTC 2775, NTC 1736, NTC 2883.74, NTC 2959, NTC 5287, GTC 114 and NTC 2050, which regulate photovoltaic installations, were taken into account. Additionally, the recommendations given by the International Civil Aviation Organization (ICAO) and the Colombian Civil Aeronautics for the installation of heliport lighting were taken into account. The following are some calculations made for the execution of the heliport light bank design at the 15th General Santander Infantry Battalion.

According to the plan and study carried out, it is established the use of 42 lamps for a minimum total required consumption of 3100Wh, located in the following coordinates: Latitude: 8.22159295 degrees Longitude: -73.32493 degrees as shown in figure 5.

Figure 5. Satellite image of the Heliport at the established coordinates.

According to data taken from the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM), such as month-to-month radiation, it is determined that April presents a lower radiation index with 3.6KWh/m2 with a monthly energy of 93KWh and an energy factor of 1.16. We proceed to calculate the performance of the installation with the following equation

$$R = 1 - \left[(1 - b - c - v) \times a \times \frac{N}{Pd} \right] - b - c - v$$

Where b is the coefficient of losses by the batteries, c is the coefficient of losses in the inverter, v is the coefficient of other losses in the installation, a is the coefficient of discharge of the batteries, N is the number of days of autonomy and Pd is the depth of discharge, obtaining a result of 0.6407.

Then the energy required for the system is calculated taking into account the most critical month:

$$E = \frac{Et}{R} (Wh / dia)$$

Where Et is the energy in the most critical month (April), obtaining a necessary energy of 4838.45Wh.

- Solar Panels

Photovoltaic panels are devices that can transform solar energy into electrical energy (Akter et al., 2020; Imthiyas et al., 2020), they consist of cells that operate according to the principle of the photoelectric effect (SunSupply, 2017). For obtaining the number of panels, according to the power required by the system, taking into account the obtained data presented in Table 5.

Table 5 Data for the calculation of the solar photovoltaic plant

VARIABLES	**VALUE**
solar declination (δ)	-23.371

sunrise angle (Ws)	-86,419
sunrise angle on an inclined plane (Wss)	-90,497
site inclination (β)	9,3731
eccentricity factor (Eo)	1,032
radiation on the horizontal plane (Hd,m(0))	81,55Wh/m^2
brightness index (Ktm)	0,530
diffuse fraction of the radiation (Fdm)	0,40
diffuse radiation (DdM(0))	1881,27Wh/m^2
radiation reaching the inclined plane (H)	2818,726Wh/m^2
correction factor (K)	1,130
direct radiation on the inclined plane (H(β,α))	3185,391Wh/m^2
diffuse radiation on the inclined plane (D(β,α))	1868,714WH/m^2
albedo radiation on the inclined plane (Al(β,α))	6,275WH/m^2
total radiation on the inclined plane (G(β,α))	5060,381Wh/m^2
peak solar hours (HPS(h))	5,060 horas
peak power (Pp)	956,144W

$$Np = \frac{Pp}{0{,}9 \times P_{mod}}$$

Where Pmod=250W; a required number of panels of 4,249 is found, approximating to 5 panels with a module of 250 W.

- Accumulators or Batteries

They are the elements in charge of storing energy when the photovoltaic production exceeds the demand of the application, in order to deliver it to the user in the form of direct current. This element turns out to be of great importance in the application of solar panels, due to its role mainly of accumulating energy and stabilizing the voltage of the respective installation (Sun & Zhang, 2020; Vamja & Mulla, 2020; Zand et al., 2020).

For the calculation of the battery consumption, a discharge capacity of 75%, an autonomy of one day, a voltage of 12V. and a temperature correction factor of 1 is taken into account.

$$C_{ne} = \frac{E(L_{md)} * N}{P_{DE} * F_{CT}}$$

Obtaining as a result a nominal capacity of the battery of 537,606Ah for which 6 lithium batteries of 6Ah at 12V were selected.

- Regulator Dimensions

They are elements that allow to charge the batteries properly and additionally avoid overcharging and excessive discharging of the batteries (Sun & Zhang, 2020). Whenever batteries are used in a photovoltaic system, there must also be some type of regulator that supports the needs of the battery.

$$I_{ent} = FS * I_{CS} * N_P$$

Panel short-circuit current (SCC): 8.65 depending on the panel to be used

Safety factor (SF): 1.3

$I_{in} = 56{,}225A$

$$I_{out} = \frac{SF * (P_{DC} + \frac{P_{AC}}{\eta_{inv}})}{V_{Bat}}$$

Power in alternating current (PAC): 3100Wh

Power in direct current (PDC): 0

Inverter efficiency (η_{inv}): 0.9

I_{out}=373.14815A

- Inverter Dimensions

Knowing that solar panels deliver direct or direct current, it is necessary the use of current inverters; for conversion of the same; in case of requiring direct or direct current (DC or CC) to alternating current, to feed some points of lighting or appliances, which necessarily work with alternating current.

$P_{inv} = FS * P_{AC}$

Safety factor (SF): 1.3

$P_{inv} = 4030Watt$

3. CONCLUSIONS

Problem-based learning is presented as a strategy to strengthen the teaching-learning process.

Classroom Projects are a methodological proposal that allows incorporating the competencies acquired by the student in different Learning Units to solve a problem.

Learning styles are a good tool for the selection of collaborative work groups.

Renewable energies such as photovoltaic solar energy is an effective solution for areas that are not interconnected to the electrical distribution network.

By measuring the area of the heliport, it was possible to identify and delimit the obstacles for the location of lights and solar panels, taking into account the angles of radiation and geographical conditions that hinder the landing and takeoff of their aircraft.

Due to the fact that the heliport components are specialized, they are not easy to acquire and require a high budget, so it is necessary to be as strict as possible in the calculation for the optimization of resources.

The topographic design was carried out, which is of vital importance to have a vision and dimensioning of the system to be implemented.

According to the standards and recommendations mentioned in the previous article and the topographic analysis, the use of 42 infrared lamps powered by 5 photovoltaic panels of 250W was established.

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