Competency Assessment Methodology for Online Engineering Laboratories.

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Abstract— **This work shows a new way of evaluating online based competency-based methodology is applied on Flipped Learning (flipped class), applied in the Teaching learning process, in the period September 2014-September 2018 of the subject of Automatic Control of the Faculty of Electromechanical Engineering of the National University of Loja in Ecuador (UNL). The experiments were performed in delayed time, virtual and remote, a copper crushing prototype and a binary distillation column, respectively. Likewise, among the indicators that have been considered to evaluate the use of this method in students are: self-evaluation, co-evaluation and hetero-evaluation.**

keywords——**Control Systems, Competencies, Flipped Learning, MATLAB® y Online Education.**

I. INTRODUCTION

THIS article deals with online labs for engineering teaching and learning, which allow students to access experiments anytime, anywhere through an internet connection. The objective of this work is to describe the procedure and instruments designed for the effective evaluation of competency-based learning in online laboratories in the area of industrial control and instrumentation.

Proof of this, are the results obtained with a group of students of the subject of Automatic Control in the Electromechanical Engineering career of the National University of Loja (UNL), in the period September 2014-August 2018, the 8 cycles were divided into 2 groups (2 years without using the LV, that is, September 2014-August 2016 and 2 years using the LV, that is, September 2016-August 2018), assessing only the grades from 7 to 10, values that students need to pass each subject.

Next, it is shown in Figure. 1, the mind map of what a competence means, starting from the left and continuing clockwise, it indicates what an ability, skills, competencies

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and finally what a talent is, that is, a mastery at a higher level in a specific field.

Fig. 1. Representation of the four axes that must be considered to develop a didactic strategy.

Below are some applications that have been made in online virtual laboratories, in the subjects of Automatic Control.

Currently, online laboratories (online) are made up of remote and virtual laboratories, highlighting three general types of laboratory in engineering education; namely, practical, virtual and remote; each of them with its own advantages and disadvantages as mentioned [1]. The use of these laboratories requires that the student know how to make the connections of the model through a data acquisition card, for example, so that all the sensors are connected to it [2].

At the Marta Abreu de las Villas Central University (UCLV) in Cuba, a Distance Laboratory System (SLD) has been developed that is used both in teaching and in research related to the field of Control Engineering. System performance (SLD) is evaluated by the capabilities and functionality of the proposed remote laboratory platform [3]. In the system that proposes the control of the filling of a model of interacting tanks with the application of a classic PID control in order to maintain the level at a desired value when manipulating the closing and opening of the solenoid valves, this is explained in more detail in [4].

The UCLV has also carried out other hybrid applications in automatic control, through remote laboratory practices in combination with face-to-face teaching in the subject of Automatic Regulation I, at the Polytechnic University of Madrid. In this sense, the UCVL developed a Remote Laboratory (SLD) system. Whose objective is that both institutions can adequately combine face-to-face and remote practices for teaching automatic control subjects [5].

Another experience is that developed by the University of La Rioja (UNIR) in Spain, applied to approximately 30,000 students geographically dispersed in different places, in the context of an educational model to carry out practices and

evaluations purely online t [6].

In [7], the architecture of a real-time environment for numerous remote experiments is described. The environment is created with web standards such as HTML5, so that the user does not need to install any plugins for the exchange of messages and the use of remote practices with Google Coder.

Finally, in [8], an experimental study is appreciated to examine the acceptance of technology by students and the process of adopting an online learning environment that incorporates web-based resources, such as virtual laboratories and its theoretical and practical implications for educational use. Achieving a reach in this learning environment achieved 86% success.

In short, access to virtual laboratories with an online connection allows simulating learning environments, which are designed to be attractive and educational to those who use them and also allow them to be complemented with traditional formal learning programs that interact with industrial instrumentation. through a variety of learning experiences [9].

Within these laboratories, the remote ones stand out due to the availability of 24/7 access, that is, 24 hours every day of the week, bringing trainees closer to the management of equipment with industrial characteristics, which allow real

experiments to be carried out through of the Internet and be in contact with the experimental system [2].

II. METHODOLOGY.

Teaching and learning is based on the competency methodology, Flipped Classroom and Flipped Learning, which allow to show if the intervention or the process carried out is effective, it is necessary to bear in mind that the student is active and not only a recipient of knowledge, in addition, that learning is self-managed assisted. To better illustrate, the content of the 8 units of the subject of Automatic Control is presented in Figure. 2.

In addition, this course will be developed under an online regime, which meets the following conditions:
- Lasts a total of 144 hours, divided over 20 weeks.
- Organized in eight modules: 60 hours for the first 4 units and 68 hours for the V, VI, VII y VIII units, respectively.
- The design responds to a balance between autonomous and collaborative learning.
- Activities are carried out that demand the sharing of experiences and knowledge; as well as group work.

Fig. 2 . Mind Map in which the 8 Units that make up the matter of Automatic Control are indicated, See in the CIEM [10].

A. Deferred Time of Automatic Control practices.

Currently due to the pandemic, it is important to note that the time of Internet use has doubled and the devices that have been used the most by professionals are cell phones and by students their laptop or desktop PC. By the way, age and level (rural or urban), allows giving a guideline regarding the social network, which is most used by certain groups.

Indeed, as mentioned above, the difference between traditional teaching, where the class is centered on the teacher and the student is defined by being rote and the class inverted. (Flipped Classroom), where the process is reversed in the classroom. It is mainly due to the fact that the latter uses learning tools invested in the student, with which it is achieved that the student is the protagonist of the educational process, and, turning the teacher into the facilitator, guide, motivator

and mediator of the teaching and learning process.

On the other hand, the content of the CA subject is characterized by a constructivist learning [12].
- Cognitive theory
- Psychology
- Neuroeducation

In addition, significant learning [13].

- Contexts
- Projects/Challenges
- Experiments

Likewise, as it is a flipped class, the student generates certain anticipated knowledge, which is developed prior to the beginning of the class. The educational resources used to

generate this prior knowledge are, among others: videos, interactive videos, presentations, questionnaires, etc. This material that the student must first study is taken to a debate, using technological tools (simulators, for example, MATLAB®). The results are socialized, analysed, discussed and agreed in class with the teacher's accompaniment.

B. Virtual and / or Simulated Time, applied to Automatic Control practices (CA).

The simulation consists of placing a student in a context that limits some aspect of reality, in addition, that promotes the understanding and application of new cognitive skills for the future professional function, that is, there is active learning and high self-motivation [11].

Goals; Using simulation as an application tool allows students to:
• Investigate certain processes, from the scope of the CA.
• Develop interactive applications that allow the application of certain CA strategies (PID, Smith's Predictor, among others).
• Evaluate to what extent the use of simulators allows to improve the understanding of process control, carrying out practices in real time, for example, in the subject of mathematical modeling.

The transmission of knowledge; it was done using chat, questionnaires, readings and the use of collaborative ecosystems in education.

The production of resources is done using; Power Point; genially, prezi, Canva (Infographics), Mind Maps (Coggle). Dynamic Powtoon Presentations.

Collaborative work; It will be given by autonomous characters and agents (Artificial Intelligence).

The communication channels are; the use of videos of virtual environments, which will allow a very good sense of presence.

Teamwork was implemented and / or motivated through co-evaluation by group members, with previous readings and content before class, which can be found on social networks. In addition, the student is proposed to practice in simulators mounted on the network.

This time is characterized by adaptive learning.
• TICs
• Virtual Environments.
• Simulation.
• Artificial intelligence.

Likewise, it should be noted that it is studied from the II to the VIII unit of the matter of Automatic Control, in a virtual time, beyond the theoretical moment with the use of simulators, proof of this are the mathematical models and semiotic representations (which allow the individual to externalize their mental images, that is, to make them visible or accessible to others), which make use of a GUI (Graphical User Interface) in the environment of MATLAB®, As can be seen in Figure 3
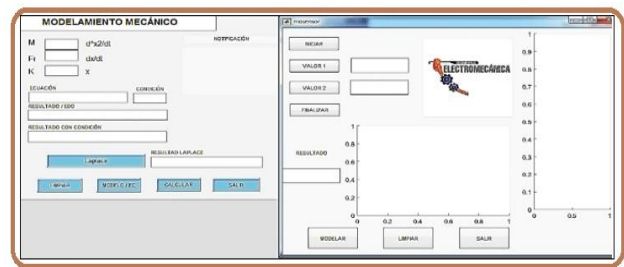

Fig. 3 . GUI (Graphical User Interface) in the MATLAB® environment, which contains the mathematical model of a mechanical system.

Next, it is indicated in Figures 4 and 5, respectively, the designs of a copper crushing prototype and a Binary Distillation Column (CDB) that were drawn in SolidWorks, to later be imported into MATLAB® / Simulink, for appreciate its 3D simulation.
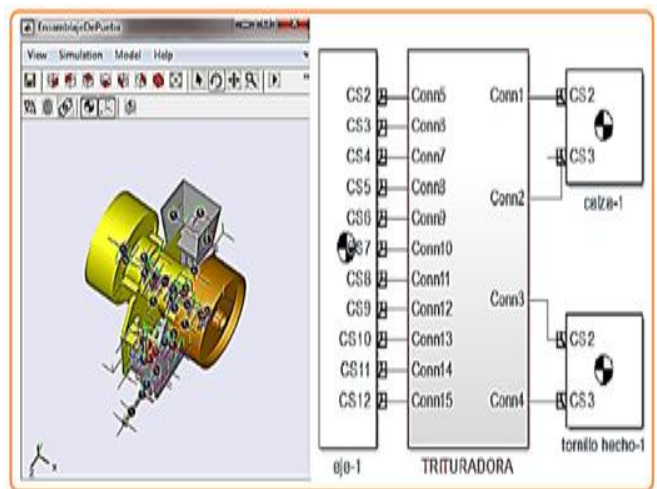

Fig. 4 3D simulation of the crusher on the left and what is automatically generated in block diagram on the right, Source: Author.
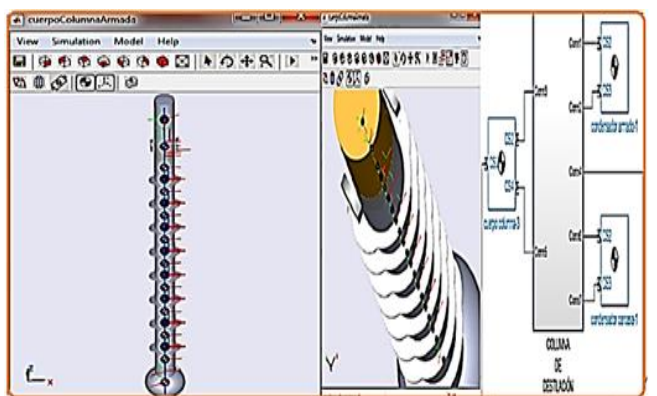

Fig. 5 Screenshot of the CBD screen, Source: Author.

C. Remote Time, applied to a Copper Crushing prototype.

Currently, to provide a quality education, improve motivation, dynamism in learning and student performance, it is necessary to formulate new academic proposals, based on different approaches and learning theories.

Technologies such as AI, simulation are becoming a

didactic resource to promote educational inclusion, critical thinking and development of technological skills during the teaching-learning process of science. (9).

Remote laboratories (LR) are technological tools composed of software and hardware that allow students to remotely carry out their practices as if they were in a traditional laboratory (LT), generally the access is made through the Internet (A remote laboratory, it is not a simulator) [11].

Next, it is shown in Figure. 6, the experience carried out at the UNL, where the user, that is, the administrator of the MFC or the student of the CIE (Electromechanical Engineering Career) of the UNL, has to provide an electronic identification, to access any of the practices.
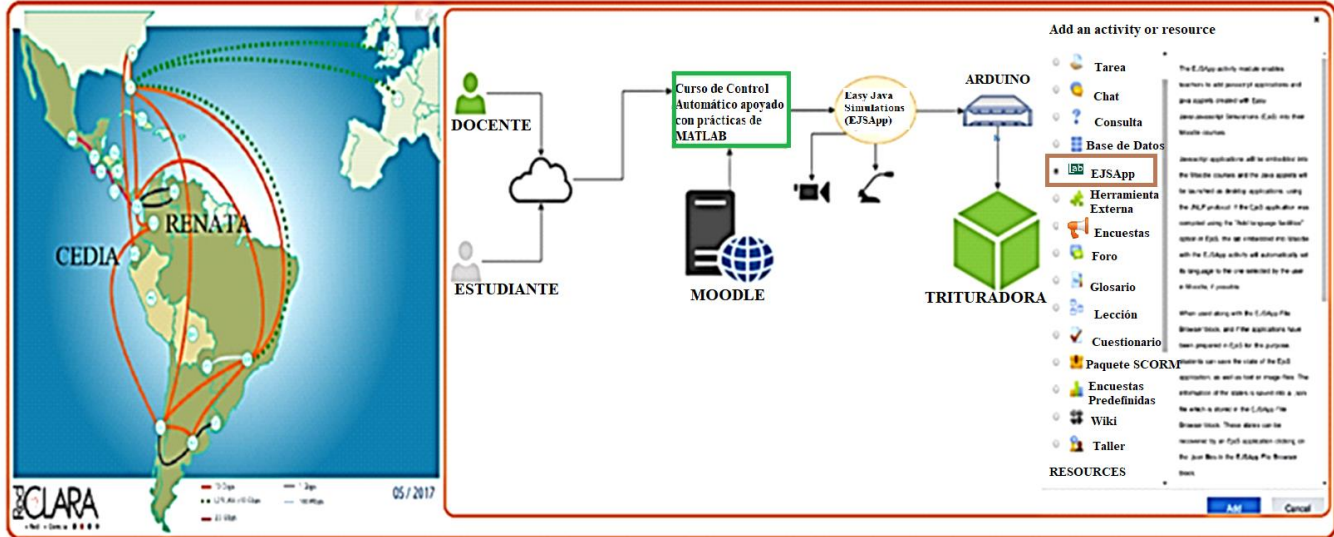

Fig. 6 Architecture to access Automatic Control practices, which includes the RedClara for CEDIA-Ecuador and the Moodle plugin, Source: Author.

The remote-time practice is structured as follows: communication strategies to meet the objectives, learning resources, activities to meet the general and specific objective, to carry out the practice, and it is only carried out for the crushing prototype, when starting. The page of this site will show three sections:

Information Section; where it is appreciated: Start Guide, Presentation and Meet the tutor.

Communication Section; Instructions.

Interaction Section; where it is defined: Meeting point and support workshop.

Characteristics.

• The course lasts for Unit V, VI, VII and VIII, respectively, with simulated and practical activities based on the theoretical orientations.

• Additional materials are offered to ensure continuity of learning on the subject.

• The participant submits progress of the work they carry out through the virtual education platform.

Overall objective; Acquire the ability to identify and control the weight at the exit of the copper crushing prototype, through the closure of the position of a screw that closes the crusher plate, statistical measurements, analyzing graphs, and therefore developing a thought. randomization that allows you to apply it to the solution of problems and situations in which there is a high degree of uncertainty through the use of probability distributions and simulation through the use of MATLAB® software.

Specific Objectives:

• Know the basic concepts of Systems Identification and its statistical culture, in the identification of systems, making use of the CADCS.

• Learn about the management of MATLAB® software, for process control, as a programming language and making use of the Simulink environment.

• Increase the knowledge of models and their application in simulations using control strategies such as PID, Smith's Predictor, MPC and LQR.

Skills to Develop:

Participants learn and understand the basic concepts of Systems Identification, statistics, as well as the use of MATLAB® / Simulink software, use of toolboox necessary in the MATLAB® programming environment, in the design of Control systems.

In addition, theoretical-practical topics of the implementation of control systems, basic programming with the use of the script, functions and graphic tools.

Likewise, the constructivist method is used, starting from the review of the previous knowledge of the participants to proceed to the construction of new knowledge from the use of dynamic methodological strategies (problem-based learning, collaborative work, case studies, project-based learning, among others), books, videos and spaces for communication such as forums, messages..

The student is recommended to use the following techniques:

• Incorporate folders that are organized according to the control strategies to be carried out.

• Download the documentation found in the virtual

community.

• The collaborative activities are oriented according to simulated practices with MATLAB®: PID, Smith's Predictor, MPC, LQR and Fuzzy Logic.

• The resources are raised in a transversal way, that is, common with other units and subjects of the cycle or independent, only of the unit or subject.

• Form work groups of no more than four students, depending on the total number of students in the course.

• Be on the lookout for synchronous and asynchronous classes online.

Available Practices; Apply the classic PID control strategy

and another based on Smith's Predictor, in real time and delayed (that is, a video of the process). Finally, based on MPC and LQR, this is only as simulated time.

Once inside the website, the student must choose one of the two control strategies: PID and Smith's Predictor, as seen in part a) of the Figure. 7, in section b) of this same figure an interior view of the assembly of the NEMA 23 stepper motor is appreciated, coupled to work with the gin wheel system, in c) and d), respectively, the complete system is observed , which includes two bands used at the exit of the copper crushing prototype, based on MPC and LQR, this is only as simulated time.
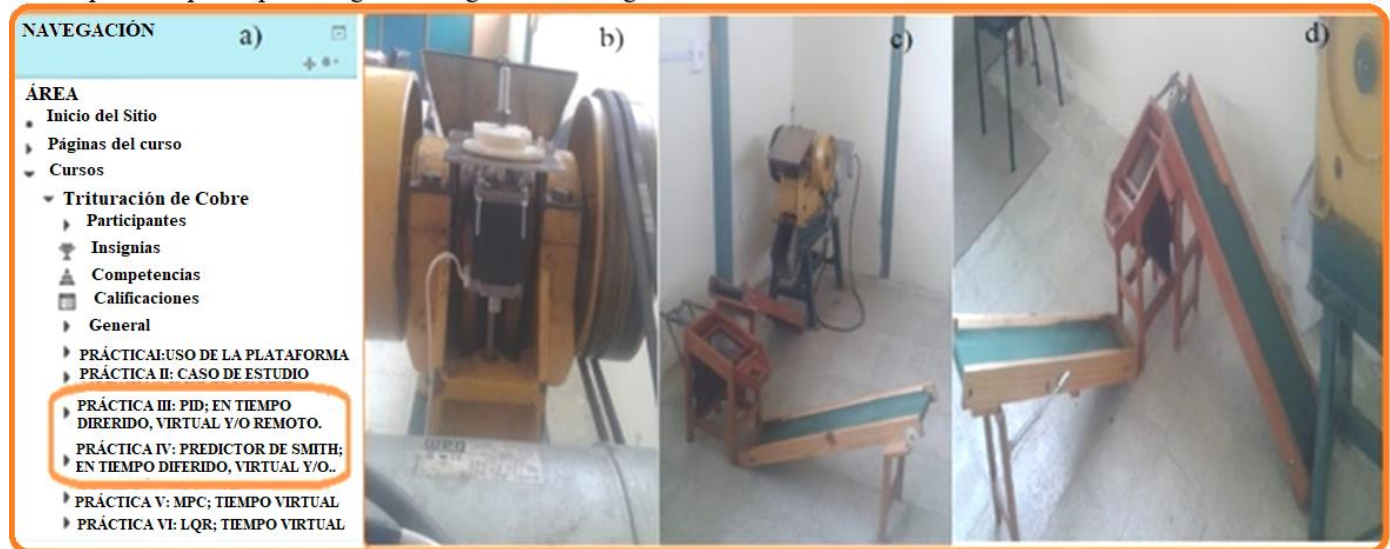

Fig. 7. a) Access environment to practices in deferred, virtual and / or remote time, applied to the copper crushing prototype, which can be seen in sections b), c) and d), respectively, of this figure, Source: Author.

Next, it shows the moments that a class has, in the three modalities raised in this methodology.

Class moments; Remote.

As in the times analyzed above, this practice has three moments.

I stage:

Start, the team is organized and integrated (which are generally groups that come from the beginning of the course, a work plan is designed, the requirement criteria are integrated with which the product will be evaluated

II stage:

It refers to development, where the team is generating its own knowledge, the subject of group work is the subject of inquiry assigned by the teacher, in this case it is the use of PID controllers, Smith's Predictor, MPC, LQR, applied to the

copper crushing prototype.

And PID controller, LQR and based on Fuzzy Logic, in the CBD.

III stage:

Closure, is the result found by the team.

The development of these stages is somewhat similar in the last four units, as can be seen in the Figure. 8. Where the knowledge learned is put into practice and the competences in the student are enhanced.
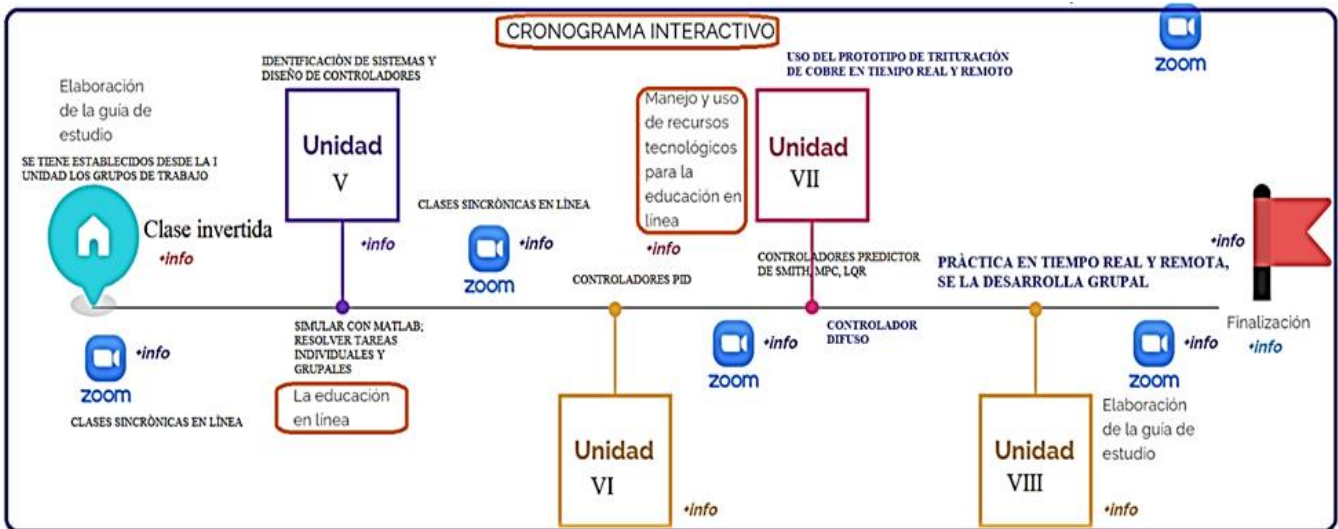
Fig. 8. Inverted class methodology applied to the prototype of copper crushing, simulated and remote time, Source: Author.

III. RESULTS

For the qualification of this activity it is considered:

• Each item must relate to the topic of inquiry, in the case of real-time practice.

• The construction of the learning community must be creative, innovative and academic, to motivate the consolidation of the community, that is, the student must develop these competencies, autonomously and in groups.

• Communication mechanisms should facilitate dialogue and participation, forums, asynchronous meetings for example through zoom.

The laboratories evaluated when applying this methodology by competencies, is that of the UNL, where, the experience of classes in which the theoretical part predominates, such as Units I, II and III, respectively, significant learning is highlighted, where develops the knowledge of the students, for example, the flipped class through videos, for the teaching of the subject of Automatic Control.

In addition, for the evaluation, the sense of information shown in the Figure is defined. 9.

Fig. 9. The criteria must have a respective activity to achieve a stated objective.

The evaluation has a formative and summative approach, being obtained for the period 2014-2018. Using this methodology the results, shown in Figure. 10.
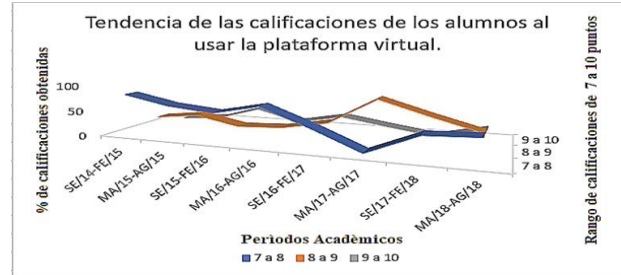

Fig. 10 Academic results obtained by CA students, in the periods September 2014-August 2018, Source: Secretariat of the CIE.

A. Results obtained when using OER.

The OER (Open Educational Resources) and the RRSS (social networks), most used are indicated in Table I.

TABLE I
REA, MOST USED BY STUDENTS.

RESULTS PRESENTATION.

Internet Connection Time	More than 8 hours	
Devices used to connect	Cell phone and laptop	
Frequent uses of Internet and RRSS	Entertainment, information and chat	Work and Education
Most used social networks	Facebook, Instagram and WhatsApp	LinkedIn and Twitter

Frequently published content	Texts with images and photographs
Advantages of using RRSS	Communication, information and resolve labor issues
Evaluation of the RRSS	They are a good tool for certain things

Next, in the Table. II, the distribution, according to its deferred, virtual and / or remote time, of the practices of the subject of Automatic Control is presented.

TABLE II
TIME DISTRIBUTION: DEFERRED, SIMULATED AND / OR VIRTUAL.

Unids that make up the matter of CA.	Theoretical	Diferred	Virtual	Remote
I, II, III y IV	x	x	With the help of MATLAB®	Not applicable
V, VI, VII y VIII	x	Crushing prototype video	CBD and Pro.Tri. With the help of MATLAB®	Crushing prototype.

IV. CONCLUSIONS

This methodology based on Flipped Learning promotes meaningful learning of control strategies: PID, Smith's Predictor, among others. Mainly because students are at the center of the educational process, and not just recipients of CA subject content.

This methodology allows students to develop self-managed learning assisted by the teacher throughout the teaching-learning process. When carrying out practices in delayed, virtual and / or remote time of a copper crushing prototype and a binary distillation column.

In the period of September 2014-September 2018 that this methodology was used, it gave very good results and that were the basis so that in this period of pandemic the students could do remote practice, with the limitations that it implied, not being able to prepare the practice, that is, carrying stone to crush.

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