Laboratory in the context of the Sars-CoV-2 Pandemic to Strengthen the Competencies of Students of the Computer Systems Engineering Program

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I. INTRODUCTION

From March to November 2020, the Ministry of Education (Minedu) in Peru has reported that 144,000 university students have had to abandon their studies in the country due to the pandemic. Reaching this figure, a dropout rate of 15% of a total of 961,000 university students in the Country, as shown in Fig. 1. Being the relevant thing that, without pandemic state; There was already a 12% dropout of students due to economic issues and lack of motivation due to the achievement of the competences that they do not reach. This situation is different depending on the type of management of each university. In the case of public universities, the dropout rate is 9.85%; while in private universities this indicator reaches 22.5%. [1]

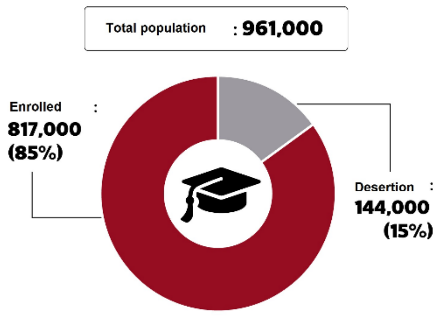


Fig. 1. Dropout of University Students in Peru.

We can point out that there are structural problems in the educational part of the country as in many others. However, the State has taken measures to stop the growth of students who drop out due to the health emergency in the country. For which, different strategies and containment actions have been applied to date in the normative and pedagogical field for the strengthening of institutional capacities. In support of connectivity, it has made investments of S / 30.8 million soles, in the distribution of chips that allow internet access; Most of them in universities in the city of Lima (15,158), Puno (7,475), Cusco (7,466), Apurímac (5,102), Lambayeque (4,954), Áncash (4,652), and Cajamarca (4,522). Benefiting 100% of teachers and 70% of students. [1] As an analysis of the aforementioned lines, it is important that educational institutions adapt the courses that motivate students to continue specialized engineering studies, through the use of information technologies. [1]

Traditional education was based on an essentially passive transmission model, lacking interactivity and oriented towards the pure transmission of knowledge. This model is known as programmed teaching, and it does not focus on the process of incorporation of knowledge, but on the process of exposure. Obtaining explanatory and argumentative clarity was essential for this model. However, the constructionist model is oriented to the way in which knowledge is incorporated from the mental and cognitive models that are acquired and based on the experience and reflection of this knowledge. For this model, learning occurs in a scenario composed of a series of interconnected variables such as the context, the group, the stimulation conditions, the expansion of cognitive possibilities, among others, that provoke motivation for the investigation of new knowledge. [2] Which, for our problem of social isolation due to a health emergency, raises the question: How to reduce the abandonment of practical courses by engineering students?

An efficient instructional design using ICT should be structured under the following factors: The theoretical orientation that comprises two aspects. On the one hand, the integration of the network (structure, media and communication systems), and, on the other hand, constructivism, understanding of meaningful learning in students to develop learning environments that enable the construction of learning. That is to say, a collaborative approach, diversified in didactic perspectives and framed in an authentic context. [2]

In this context, the formulation of the learning objectives must be concise and appropriate to the process and level of learning that the student must reach in each case. It is not the same to know than to assimilate, or to recognize than to apply, or to distinguish than to relate. This process is called a learning taxonomy. Each differentiated learning objective will require a different instructional model. [3]

The contents or nature of the matter, that is, its own characteristics; Science subjects tend to require more exploration, analysis, experimentation type activities, use more graphic images, while "letters" cover a wide range of possibilities: mnemonic, reflective, relational, contrasting information, among others. All this has a direct relationship with the theoretical orientation and with the technical possibilities that the remote training system offers. [3]

The characteristics of the students, their cognitive profiles (learning styles and cognitive styles, meta-cognitive skills, etc.), their motivation (both for the content to be learned and for the environment in which the training is developed), the degree of computer literacy (which will mediate the exploitation of the possibilities of the Internet and its predisposition), and the social context in which they are immersed (and its influence on facilitating or not collaborative learning, highlighting in this aspect the importance of the cultural factor) . [4]

The technical possibilities: the gradual extension of the bandwidth, the improvement and extension of the networks, the capacity of the machines and peripherals and other types of telematic and computing factors, will make possible an increasingly multimedia medium rich in didactic possibilities for the development of more varied and innovative training programs. [4]

On the other hand, new information and communication technologies in university classrooms have promoted the development of alternative pedagogical modalities to the traditional ones. The flipped classroom, or Flipped Classroom, has been considered a suitable model for teaching engineering subjects, because it is useful to optimize work time in the classroom and prepare materials for students who learn outside of it. [5] In the same sense, it can be reaffirmed that technological advances have caused the field of education to be influenced by the emergence of new teaching and learning models mediated by the large number of digital resources and electronic devices that teachers can access. One of the methodological approaches that is emerging as a consequence of educational innovation is flipped learning. This teaching and learning model is based on the idea that students can visualize and work on the contents of the next sessions in the classroom outside of the academic environment, in order to spend as much time as possible in solving problems of the class and the deployment of more practices, participatory and active work. In this way, greater motivation is achieved that benefits the learning process. [6]

The peculiarity of the flipped classroom method lies in the change of learning roles, where the teacher acquires a secondary role as a guide and the student a primary role as an active agent. The trend of implementation in the higher education stage is increasing and it is increasingly common to hear teaching experiences that revolve around its application in the classroom. [7]

In relation to what is indicated above, a great challenge is presented to universities in Peru, regarding the way in which they should develop learning sessions in this new context. In this sense, we can specify that to date the engineering programs of many higher-level educational institutions; They continue to work under educational models and methodologies aimed at the training of face-to-face education; wasting the great opportunity presented by the use of virtual learning environments; however, conducting experiments remotely is often costly in terms of time, money and energy, as it requires the development of specialized infrastructures. Although nothing can be compared to actual interaction with physical laboratory equipment, fortunately there are other options that provide students with the ability to interact with physical laboratory equipment and materials from a distance. Thus, a remote laboratory is normally understood to be one that exists and can be manipulated remotely over the Internet, making use of Webcams, specific hardware for local data acquisition and software to cover fundamental aspects of a course. For which use is made of generic or specific computer software to activate, monitor or control various devices in the study area, as shown in Fig. 2 [8]

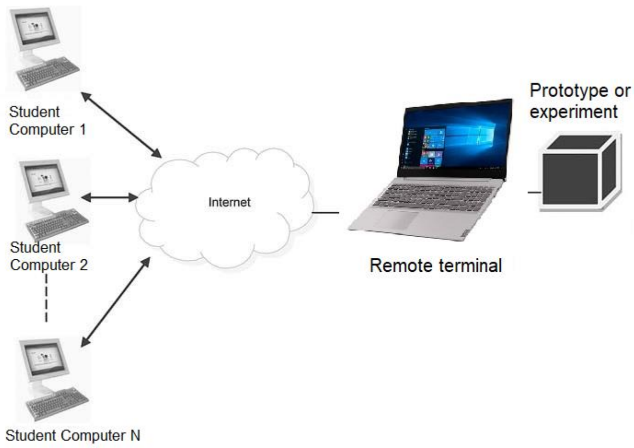


Fig. 2. Remote laboratory architecture.

In this scenario, the Computer Systems Engineering Program of the Universidad Privada del Norte, has been analyzing various proposals to provide the best training to its students. Reason why, it is required to guarantee the fulfillment of the achievement of each one of the learning sessions through remote dictation. This fact is relevant, because if the class sessions do not ensure the achievement of learning, a high risk would arise in the training of professionals, who will not acquire some of the capacities, skills and attitudes established in each program. That is why it is essential to establish a learning methodology for engineering courses, which allows guaranteeing the academic quality offered. In this sense, we ask ourselves, in what way can the student's learning achievements be guaranteed under the modality of remote education for courses with laboratory experiences of the Computer Systems Engineering Program of the University North Private?

The present research proposes to develop a methodology that allows to guide other engineering programs to implement remote laboratories using technology to guarantee the learning achievements of the Robotics Workshop course of the Computer Systems Engineering Program of the Universidad Privada del Norte. For this, within the various learning methodologies at the university level that have been analyzed in this research; The methodology called “Flipped Classroom” is being considered, which allows the development of a relatively new pedagogical model; that in the last decade it has been having very good results in various institutions recognized for providing high-level academic training; such as the Massachusetts Institute of Technology - MIT and Harvard University to facilitate a active learning in the student, since it allows the revision and level of understanding through the revision of materials from home or another work environment of the student, carrying out the practical activity in the classroom with the teacher's accompaniment; becoming the student in the protagonist of the teaching-learning process.

In this context, this research seeks to develop an instructional design to be applied in the virtual classrooms of the program, based on Flipped Classroom; which could have a significant impact on student results, as has been observed in the study presented by the Department of Economics of the Massachusetts Institute of Technology - MIT. In which it is validated that by applying the Flipped Classroom methodology, results are obtained that support the learning achievements of students who went from face-to-face training to virtual mode.

That is why, in search of taking advantage of the methodology referred to in said study, we will proceed to investigate how we can implement a methodological sequence with considering in the inverted class the application of remote laboratory experiences for the Computer Systems Engineering Program of the UPN. Considering for this, the type of course, the appropriate moments for the learning session, the use of technological tools among others. Converting the learning sessions into dynamic sessions, which allow to maintain the interest of the students; significantly reducing the number of students who drop out due to poor grades. [8] [9]

The flipped class approach is a didactic-pedagogical model that includes meaningful, personalized and collaborative learning activities that are carried out in the classroom, and direct individual instruction carried out on a computer outside the classroom. [10] An important characteristic of this model is the change in teacher-student roles with respect to the traditional model. That is, the teacher assumes a role of guide, facilitator and collaborator during the students' learning process and is no longer the only source of knowledge. Students, for their part, assume an active and leading role in the process, since they are not only responsible for the acquisition and assimilation of the contents prior to class, but they must participate in the various practical activities carried out in the classroom in collaboration with their peers. [10]

As a second factor, we refer to the importance of designing appropriate learning sessions for the thematic axis and what is described in the performance indicator of the student's result to be measured [10]. In this sense, a fundamental aspect in this research will be to maintain the alignment of achievements that are sought at the end of the semester, regarding the form of teaching-learning and the respective measurements.

The purpose of the research is to link theory with practice in courses with experimental activities through remote laboratory to strengthen the achievement of specific competencies of students in the framework of the pandemic and the accreditation process of the Computer Systems Engineering program. [10]

In search of academic excellence and continuous improvement of the achievement of the competencies of the students of the computer systems engineering program, it has been decided to adopt the ICACIT student results accreditation model. [11] International accrediting agency specialized in professional training program in computing, engineering, engineering technology, architecture and science. That it promotes the continuous improvement of the educational quality of the programs, guaranteeing that they meet the highest international standards that ensure that graduates are ready to practice their profession. Currently being a signatory member of the Washington agreement, and the first accrediting agency in Latin America member of the European Network for Accreditation in Engineering Education - ENAEE. [10]

II. Methodology

The methodology developed in this research is divided into 7 phases as shown in Fig. 3

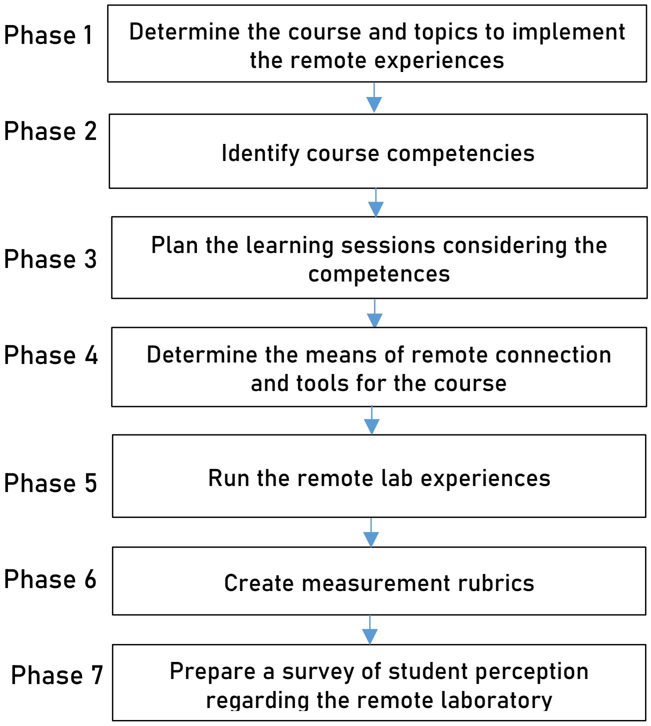
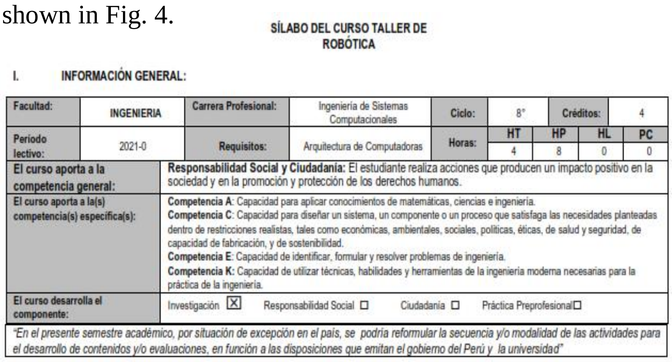


Fig. 3. Phases of the implementation strategy.

A. *Phase 1: Determine the course and topics to implement the remote experiences*

To determine the stage in which the student is with respect to the course according to the 2.0 educational model of the institution, it will be necessary to use the course syllable as a guide document; in which the study cycle and the competences that the students must develop are indicated, as shown in Fig. 4.



SÍLABO DEL CURSO TALLER DE ROBÓTICA

I. INFORMACIÓN GENERAL:

Facultad:	INGENIERIA	**Carrera Profesional:**	Ingeniería de Sistemas Computacionales	**Ciclo:**	8°		**Créditos:**	4
Periodo lectivo:	2021-0	**Requisitos:**	Arquitectura de Computadoras	**Horas:**	**HT**	**HP**	**HL**	**PC**
					4	8	0	0
El curso aporta a la competencia general:	**Responsabilidad Social y Ciudadanía:** El estudiante realiza acciones que producen un impacto positivo en la sociedad y en la promoción y protección de los derechos humanos.							
El curso aporta a la(s) competencia(s) especifica(s):	**Competencia A**: Capacidad para aplicar conocimientos de matemáticas, ciencias e ingeniería. **Competencia C**: Capacidad para diseñar un sistema, un componente o un proceso que satisfaga las necesidades planteadas dentro de restricciones realistas, tales como económicas, ambientales, sociales, políticas, éticas, de salud y seguridad, de capacidad de fabricación, y de sostenibilidad. **Competencia E**: Capacidad de identificar, formular y resolver problemas de ingeniería. **Competencia K:** Capacidad de utilizar técnicas, habilidades y herramientas de la ingeniería moderna necesarias para la práctica de la ingeniería.							
El curso desarrolla el componente:	Investigación ☒ Responsabilidad Social ☐ Ciudadanía ☐ Práctica Preprofesional☐							

"En el presente semestre académico, por situación de excepción en el país, se podría reformular la secuencia y/o modalidad de las actividades para el desarrollo de contenidos y/o evaluaciones, en función a las disposiciones que emitan el gobierno del Perú y la universidad"

Fig. 4. Syllabus of the Robotics Workshop course

The Robotics Workshop course is in cycle 8, so the student is in the autonomy stage and the teacher fulfills the role of advisor. Additionally, the student's profile is available as shown in Fig. 5

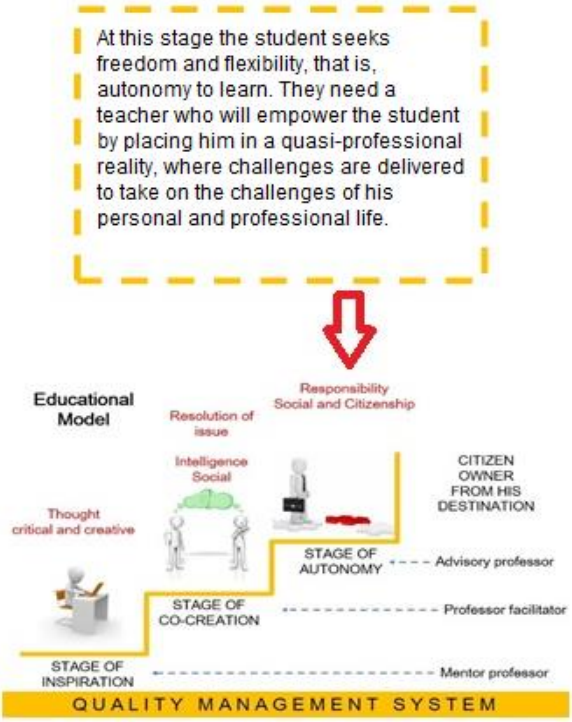


Fig. 5. Student profile - autonomy stage.

B. Phase 2: Identify the competencies of the course

Next, the competencies of the course are identified which are aligned with the results of the ICACIT student; It is important to mention that there is an initial strategic process that determines the courses, results and levels of achievement to evaluate the progress of the students, according to the stages of the aforementioned educational model, which is in charge of the Program Quality Committee; being the course competences:

General Competences:

- Social Responsibility and Citizenship: The student takes actions that produce a positive impact on society and on the promotion and protection of human rights.

Specific Competences:

- Competency A: Ability to apply knowledge of mathematics, science and engineering.

- Competency C: Ability to design a system, component, or process that meets the needs posed within realistic constraints, such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.

- Competence E: Ability to identify, formulate and solve engineering problems.
- Competence K: Ability to use modern engineering techniques, skills and tools necessary for engineering practice.

C. Phase 3: Plan the learning sessions considering the competences

To establish the learning session, we have strategically used the application of the systemic review methodology PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyzes) regarding active teaching approaches [12]. Twenty-seven original articles published in indexed scientific databases out of a total of 35 articles were reviewed, in English and Spanish, between 2016 and 2020. Adapting the effectiveness of the method called Flipped Learning, which considers factors such as motivation by part of the teacher, the guided exploration of multiple resources worked by the students [13], the development of investigation works, moments of debate and reflection; as well as oral exposure within evaluations [14]. Considering the above, the Flipped Learning model was established with the strategy of the moments of the learning session [15], as shown below in Fig. 6.

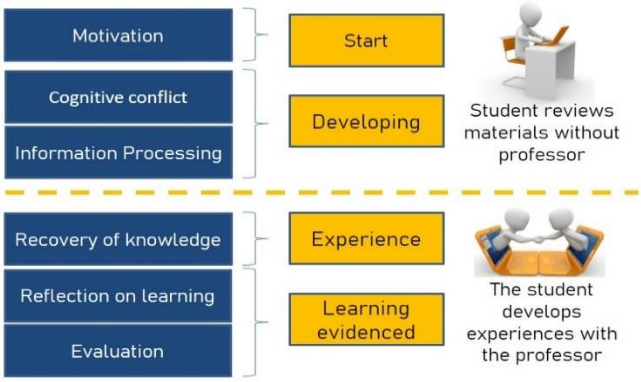


Fig. 6. Learning session structure.

This structure allows students to achieve the course competencies in the remote mode; as presented in Fig. 6. All this is based on 16 field works that are part of the final project of the course, which includes the simulation process that must be exposed in teams of students, accompanied by a report and the Oral presentation, using the simulation tool, to explain the design, programming and operation.

The university currently has a format for learning session designs. Which are reviewed by educational specialists, the coordinator and director of the program; in which the general data of the course are included; as well as part of the strategy, the statement of the activities that will be developed at the different moments of the learning session, the resources, materials, the purpose of using each resource and the times each activity will last. of support tools; among other moments of a learning session. As can be seen in Fig. 7.

DESIGN OF THE LEARNING SESSION

Guide for planning your class session (synchronous and asynchronous)

Faculty		Program	
Course		Duration of the session	
Topic		Week	
Professor		Date	
Achievement of unity		Session achievement	

ASYNCHRONOUS MOMENT (PPT Video, PDF, Additional Resources, Forums, etc.)

RESOURCES / MATERIAL What resources / materials will I publish in the Virtual Classroom?	PURPOSE OF THE RESOURCE / MATERIAL What is the utility for the student?

CLASS SESSION PLAN

TIME OF THE CLASS SESSION	EXERCISE What activities will I do?	PURPOSE OF THE ACTIVITY What am I going to do it for?	DESCRIPTION OF THE ACTIVITY Detail of the activities carried out by the teacher and the student	RESOURCES / MATERIAL What resources or materials will I use?	TIME Execution minutes
START Videoconference at the beginning of the class.					
DEVELOPMENT Synchronous activities developed during scheduled class hours.					
CLOSING Class session closing activities.					

EVALUATION FOR LEARNING

INSTRUMENT / TOOL / EVALUATION STRATEGIES What instruments and tools do you apply for the evaluation?	EVIDENCE OF LEARNING How do I know if my student learned?

Fig. 7. Learning session structure.

D. *Phase 4: Determine the means of remote connection and tools for the course*

To determine the most appropriate tools to be used in the learning sessions, it is necessary to consider factors of evaluation of costs for licenses or the choice of free or free use tools, the amount of bandwidth that will be required to sustain both the application of videoconference, as well as the traffic generated by the application of the software, terminal resources or the teacher's computer with respect to the RAM memory capacity required for these sessions. In that sense, after the analysis and tests carried out; The tools Zoom, Sketches Arduino, Proteus and Tinkercad were chosen as a means of remote interconnection in the Robotics Workshop course, during the second semester of the 2020 period; being important to state that the university has Blackboard Collaborate as a teaching-learning platform; However, the Zoom platform was additionally required in order to allow students to enter a remote connection to master the usb port of the teacher's computer, as well as the use of the camera to visualize the experience with the programmable electronic development card Arduino and the sensors and actuators (sensors, motors and LEDs) required in robotic prototypes. Next, images rescued from the recording of the asynchronous video provided to the students by the teacher are presented, where the electronic devices and platforms to be used are presented and substantiated. As can be seen in figs. 8 and 9.

Fig. 8. Video explaining the Arduino UNO project development programmable electronic board.

Fig. 9. Video explaining ultrasound sensor.

E. *Phase 5: Run the remote laboratory experiences*

In the execution of the remote laboratory experience, the students access the teacher's computer through the Zoom platform and the screen is shared through the Blackboard Collaborate platform; In order for students to remotely start programming the Arduino board and control the peripherals connected to the usb port. During that moment, the teacher interacts with them to make changes in the connections and guide them during the experience using the laboratory guide, while the students carry out the programming and observe through the camera the actuation of the sensors and actuators used, as can be seen in Fig. 10.

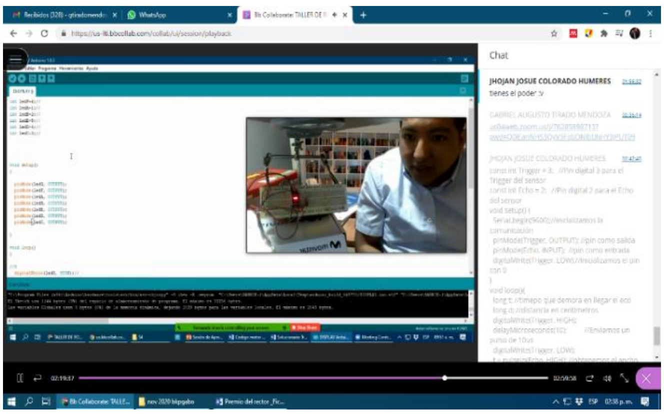


Fig. 10. Remote programming of students.

F. Phase 6: Develop measurement rubrics

For the measurement of competencies, the rubric has been developed for the student's competency K: Use of modern tools, which consists of the ability to use modern engineering techniques, skills, and tools necessary for engineering practice; which applies to the students of the course. As mentioned above, in this course 4 rubrics are used in the course; However, for the measurement of competence in the use of modern tools, the measurement is carried out in remote laboratory activities, using the rubric shown below in Fig. 11.

RUBRIC SPECIFIC COMPETITION

K. Use of Modern Tools: The ability to create, select, and use techniques, skills, resources, and tools from modern engineering and information technology, including prediction and modeling, in complex engineering activities, with an understanding of

ASPECTS	PERFORMANCE CRITERIA	LEVELS OF ACHIEVEMENT			
		LEVEL I	LEVEL II	LEVEL III	LEVEL IV
		INITIAL	INTERMEDIATE	ADVANCED	ACCOMPLISHED
To select	Selection of the appropriate tools and / or techniques 33.33%	You are unable to select the appropriate tools and / or techniques.	Little ability to select appropriate tools and / or techniques. You often need help.	Ability to select the appropriate tools and / or techniques. With minor errors.	Clearly demonstrates the ability to select appropriate tools and / or techniques.
Apply	Application of appropriate tools and / or techniques. 33.33%	You are not able to correctly apply the appropriate tools and / or techniques.	Little ability to apply appropriate tools and / or techniques. Work guided by the instructor.	Ability to apply the appropriate tools and / or techniques. Works without instructor assistance.	Ability to correctly apply the appropriate tools and / or techniques.
Analyze and interpret results	The results correctly interpreted and analyzed. 33.33%	You are unable to analyze and interpret results.	Little ability to analyze and interpret results. With serious errors.	Ability to analyze and interpret results. With minor errors	It is able to analyze and interpret results correctly.

Fig. 11. K competency learning rubric.

G. Phase 7: Prepare a student perception survey regarding the remote laboratory

For the measurement and improvement of the developed methodology, it has been necessary to prepare a survey that allowed us to collect the various opinions regarding work with remote laboratories, which was applied to the students of the course at the end of the different sessions; using the Google Form tool; considering a Likert scale from Very low level 1 to Very high level 5, as shown below in Fig. 12.

Survey 2020 - Remote Laboratory

Dear student, I would appreciate completing the survey in order to continue with the process of improving learning in the Robotics Workshop course.

Mark the score that you consider most appropriate, considering the following **levels:**

1 = Very low - 2 = Low 3 = Fair 4 = Good 5 = Very high

1. *At what level do you consider that the use of virtual tools (Proteus, Tinkercad) influences your learning?*
2. *At what level do you consider that the experience of the remote sensor and motor laboratory carried out in the course motivated you?*
3. *At what level do you consider that your learning improved in the experiences of remote sensor and motor labs conducted in the course?*
4. *At what level do you consider that your learning improved in the experiences of remote laboratories using robotic prototypes used in the course?*
5. *At what level do you consider that the application of the Inverted Class methodology used in the course; where the contents are reviewed at home and explained in the videoconference, considering in the synchronous session a greater amount of time for the experimental part?*
6. *Are you motivated to keep learning more about this course?*
7. *Would you recommend this course to other colleagues?*

Fig. 12. Student perception survey

III. Results

The results that were obtained in the development of the described method, allow the application of interconnected technological tools, allowing students to reach the student's competence K: Use of modern tools, which consists of the ability to use techniques, skills and tools of modern engineering necessary for the practice of engineering. As can be seen in Fig. 13.

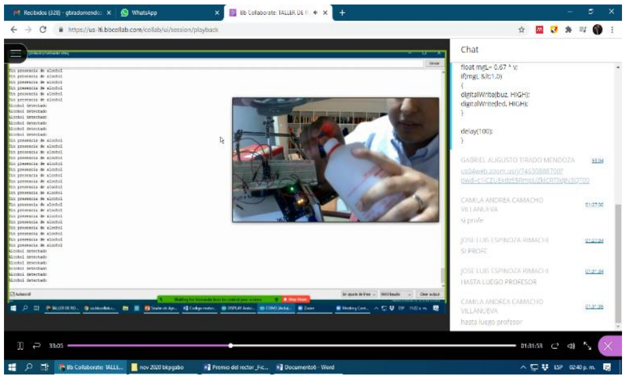


Fig. 13. Interconexión remota y soporte del profesor.

Next, we present the achievements achieved in each competition of the Robotics Workshop course, specifying that the result of all students in the course regarding the K competency, in direct evaluation of the planned and executed remote laboratory activity; it reached 84% as a result of achievement of competence, as can be seen in Fig 14.

FACULTY OF ENGINEERING
COMPUTER SYSTEMS ENGINEERING PROGRAM
LIMA BREÑA 2020 - 2

SUMMARY AVERAGE PERCENTAGE OF STUDENTS ACHIEVING THE COMPETENCE (Good and Outstanding)

CE: 11 USE OF MODERN TOOLS

CE1		ROBOTICS WORKSHOP Clase: 2204138685		TOTAL	
QUALIFICATION		Q	%	Q	%
TO IMPROVE	< 2.8	3	9%	3	9%
SUITABLE	>= 2.8 <=3.2	13	37%	13	**37%**
OUTSTANDING	> 3.2 <=4.0	19	54%	19	**54%**
TOTAL		35	100%	35	100%
Result Achieved					**91%**

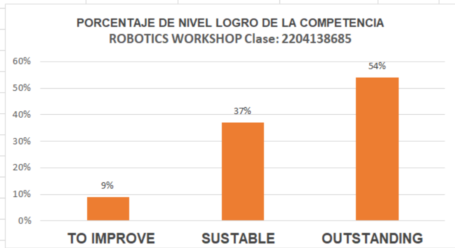


Fig. 14. Summary of achievement reaching in competition K.

On the other hand, the results achieved in each of the criteria that group the questions of the perception survey are presented. In this sense, we can indicate that it has been distributed as shown below in Fig. 15

CRITERION	QUESTIONS
Learning Process	1,5
Laboratory Activity	2,3,4
Motivation	6
Degree of Satisfaction	7

Fig. 15. *Summary of achievement reaching in the competition.*

After the distribution and the corresponding averages for each criterion, the radial diagram was applied; in order to know the results of the survey. Obtaining in the learning process criteria, laboratory activity and degree of satisfaction, the level of 4 equivalent to the result "Good" and in the motivation criterion the result of Very good. As can be seen in Fig. 16 shown below:

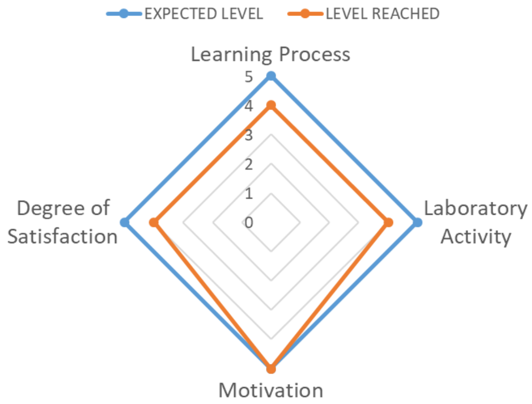


Fig. 16. Results of the perception survey.

IV. CONCLUSION

The research carried out is innovative given the context in which we find ourselves, since there are many educational institutions that present similar difficulties and do not find an economic and systematic way to guarantee the competencies of students in courses with laboratory activities and reduce dropouts in courses with experimental content. This initiative has been carried out using low-cost basic elements, equivalent to a tailor-made kit for the development of remote experiences. This reduces the investment cost that could be generated when seeking solutions with companies that commercialize this type of technological equipment in a given period.

This technological educational implementation has managed to motivate students in the course, and also the way in which students consider that their learning improved with the application of these experiences; This is evidenced in the result of the evaluations carried out in the perception survey, reaching a high result in each criterion. In addition, they report being willing to continue learning more topics from the course and recommend that other students can enroll and experiment. In addition, the assessment and impact that the development of remote laboratories causes on students, in a process of training engineering students, is recognized.

It is important to point out that a fundamental aspect to consider in the technical part of the interconnection is to contemplate a previous configuration of the security of the teacher's computer, regarding access to the mediator's private documents. Likewise, we refer that the execution for the remote laboratory experience requires rehearsing before the session the experiences to be developed to verify the adequate transmission speed and operation of the devices, in order to ensure learning.

To conclude, in the case of the evaluation tool, it provides us with a non-complex assessment scale that allows us to know the achievement of the student's K competence for the total number of students in the course, as well as what will be the improvement actions to be implemented in new experiences. In this sense, the correct approach to each of the phases is confirmed; which can be used as a base methodology for other engineering programs.

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