Learning Outcomes in Virtual Laboratories for Engineering Subjects as a COVID 19 Paradigm

Dra. Margarita Murillo Manrique[1], Mg ©. Antonio Meléndez Murillo[2]
[1]Ricardo Palma University, Perú, margarita.murillo@urp.edu.pe
[2]Universidad Nacional de Ingeniería, Perú, amelendezm@uni.pe

Abstract - The research was applied to the Faculties of Engineering, who took on the challenge in the process of student knowledge acquisition, fostering skills and attitudes that typically require a practical and laboratory component, in a virtual learning environment. The purpose was to evaluate the levels of achievement of practical learning in virtual laboratories (VL) with the use of computer software, as a challenge for the educational sector during the pandemic in such a way that they must be maintained, enhanced and adapted to the new reality due to positive result in engineering subjects. For the investigation, the students of the first and sixth cycle engineering subjects of the Ricardo Palma University (URP) and the National Technological University of Lima Sur (UNTELS) were selected as samples. The methodology considered two phases, in the first the characteristics of the sample were determined and in the second the questionnaire and rubric were applied. The questionnaire with a Likert scale to the indicators (availability of computer equipment, simulation software, laboratory guides and practical learning) and the rubric to determine the learning results through the diagnostic, formative and summative evaluation carried out by the teacher in the virtual laboratory. The results showed a high percentage at the level of good (achieved) and in some subjects an excellent level (outstanding achievement) was obtained, however, there is still work to be done on learning that is in process and at the beginning, as a need for improve the pedagogical strategies (methodologies, tools and didactic components) that the virtual, blended and face-to-face teaching-learning process will demand, from now on.

Keywords- Learning outcomes, simulators and computer equipment, laboratory guides, evaluation instruments

I. INTRODUCTION

In response to the pandemic generated by COVID-19, in 2020 and 2021, technology was incorporated into classes due to its ability to promote rapid and precise execution of procedures, which generated new ways of evaluating learning outcomes in virtual environments. This adaptation implies not only using new tools, but also modifying strategies that were traditionally used in the face-to-face environment..

For engineering subjects, technology allows work with practical experiences that encourage reflection and debate among students, in addition, it allows them to explore and conjecture in a variety of representations of engineering concepts [1].

Universities around the world have moved classes online, but whether students will learn as much as they do in physical classrooms has become a relevant globalized research question, particularly for engineering subjects in which the physical laboratories have been transformed into virtual laboratories (VL).

In this paradigm, it is not easy to establish a precise delimitation between theoretical and practical learning. As a first approximation, let us accept that the learning of theory refers to the rational assimilation of concepts, principles, laws, methods, procedures, data and information, in general, and to the process of reflection on them. For its part, learning based on practice has to do with the observation of phenomena and situations, experimentation, contact with reality, the application of theoretical concepts to specific situations, the use of instruments and problem solving [2].

This practical learning with new content in virtual environments needs to be reinforced and enriched with the use of technology, favoring motivational processes and that the content under study find greater breadth in its treatment and also contribute to motivation and meaning, provided that the relevant articulations are achieved and that the proposals for software activities also meet the requirements of developer activities [6].

Therefore, it is expected to answer the questions: What will the results of practical learning be like with virtual laboratories in engineering subjects as a paradigm of COVID 19? What does the student learn? What is measured and when is the level reached? expected quality?

In this sense, the research aims to evaluate learning achievements according to the criteria used by the Ricardo Palma University (URP) for the subjects of the Basic Mechatronics Engineering Workshop (BMEW), Electrical Machines (EM) and the National Technological University of South Lima. (UNTELS) for the subjects of Fundamentals of Electrical Mechanical Engineering (FEME) and Electrical Installations (EI), in such a way that they can be maintained, enhanced or adapted to the new reality. For which the experiences of the Mechatronics Engineering and Electrical Mechanical Engineering programs have been considered in terms of the articulation of virtual contents with aspects of the process, the objectives, the rubrics and the evidence, for the permanent construction of the improvement of learning in engineering subjects.

The methodology used for the development of the article was divided into two phases.

In the initial phase, a qualitative analysis of the new ways of approaching learning in VL for engineering subjects of the URP and UNTELS was carried out. This phase allowed to know the situation of the students regarding the means used in the virtual classes, as well as the challenges, learning and

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difficulties all related to the virtual simulation of the contents of each learning unit.

In the second phase, a study was carried out on the sample of students from the Faculties of Engineering - Professional School of Mechatronics Engineering and Professional School of Electrical Mechanical Engineering corresponding to the I (first) and VI (sixth) cycle for two subjects from each university. This analysis made it possible to determine the achievements achieved through the statistical analysis of a questionnaire and the teacher's evaluation rubric for each semester required by university policies.

After carrying out this analysis, the research quantitatively shows very encouraging results regarding the levels of achievement reached by the students, considering the multiple problems they have had to face. These learning results are related to characteristics such as gender, age, subject, academic performance, technological possibilities, among others.

Finally, after two years of pandemic, the research considers it important to rethink the strategies in the teaching-learning process in the new curricular plans that are being developed in both universities. The contents of the Learning Units (lab syllabus-guides), will be the roadmap in the recovery of experimental contents in the return to face-to-face or hybrid classes, which are already state policies for higher education in Lima Peru.

II. State Of The Art

Learning through practice

Experiential learning theory helps explain how experience is transformed into solid knowledge and learning. This theory covers four different learning methods that are used in a recursive cycle: concrete experience, reflective observation, abstract conceptualization and active experimentation [8].

Therefore, evaluation is considered of great importance in the training process of university students; however [3] explains that due to application or interpretation errors, in some cases it has only been limited to the process of qualifying and assigning a grade to a specific academic task.

In this context, [3] supports the relevance of outcomes, as one of the proposals that transcends traditional educational practices, by enabling a new form of adequate interpretation of student learning results, based on evidence and relevant information to design and implement learning processes related to their professional performance.

This is how the training of students is conceived through work with knowledge, values and skills that allow access to the understanding of reality, which is consistent with the knowledge, skills and attitudes proposed by the curricular bases [5]. If we consider the various learning strategies, the research has had to establish the main differences between abilities, skills and competencies:

- Capacity: Defined as the potential to learn to carry out a specific action that involves a series of aptitudes that come from the nature of the human being.
- Ability: Conceptually, it is the ability to perform an action or activity with skill and ease, that is, it corresponds to the same "innate capacity of the human being" but this time put into practice.
- Competence: It is the "skill" that after its constant execution begins to be carried out with a degree of expertise and excellence. As we can see, the three concepts suppose an achievement or a process in the results of learning, as explained by [2] [3] and [5].

Therefore, for the achievement of the competence, the use of practical activities can be very useful, that is, those in which there is a broad participation of the students:

- One purpose of practices in engineering curricula is to complement and integrate theoretical learning, by checking, clarifying and discovering principles and laws.
- Practices are also used to familiarize students with the manipulation of instruments and equipment commonly used in engineering practice.
- The practices facilitate and stimulate the development of attitudes, abilities and values in the students.
- Practical work is essential to achieve the investigative training of students.
- Internships allow students to frame their profession within an economic, social and cultural context.
- Internships are an ideal means to experience interdisciplinary work.
- The practice facilitates the approach to the technological resources and processes used in the different disciplines and professions [2] [5].

Consequently, learning outcomes are assessed with tools that apply direct or indirect methods, the rubric being a useful tool and widely used as a direct method of assessment. For [3], the rubric is an instrument to evaluate the results of the work carried out by a student that allows giving a grade, giving feedback and promoting their learning through a clear specification of expectations.

With the application of the rubric, the expected results are divided into parts and what constitutes acceptable and unacceptable levels of performance is explained. The rubrics are divided into four parts: Description of the task with its learning objective; achievement level scale (which may be related to a grade); task dimensions (performance indicators), which correspond to the skills or knowledge involved in it and a description of what constitutes each level of achievement in its corresponding dimension [3].

The training of engineers is a challenge for national universities, not only because of recent technological development or the need to implement sustainable projects, but also because there are social demands that must be met and anticipated in their emergence [9].

Virtual Laboratory

A very accurate definition of a virtual laboratory is the following: "Computer tool that enables virtual experiments to be carried out based on the simulation of a certain phenomenon". Likewise, for a computer simulation tool to be considered a true virtual laboratory and thus serve as a complementary tool in the teaching-learning process, special interest must be given to the design of its graphical user interface (GUI), in order to that the user can manage the virtual laboratory in an intuitive and, therefore, autonomous way [4].

For a better understanding, we ask ourselves: What is a virtual laboratory?

In the field of computing, the term virtual means "not real". In general, something that is purely conceptual is distinguished from something that is physically real. Such a distinction can be used in a wide variety of situations. According to the above, a virtual laboratory has been defined as a computer simulation of a wide variety of situations in an interactive environment; that is, you can simulate the behavior of a certain system that you want to study using mathematical models, and although you do not interact with real processes or systems, experimentation with simulated models is comparable to reality, provided that these models are realistic and represent important details of the system to be analyzed, in addition to the fact that the graphs that represent the temporal evolution of the system are complemented with animations that make it possible to see and better understand the behavior of the process [10].

A virtual laboratory has a mainly pedagogical function that allows assimilating concepts, laws and phenomena without having to wait long periods and invest in infrastructure. It is also a tool for data prediction and verification for the design of increasingly complex experiments [12].

In addition, they have a higher degree of security since there is no risk of accidents in the environment as there are no physical equipment or devices. Another no less significant advantage stems from the economy, since less is invested in equipment, materials and reagents.

From the environmental point of view, by not using reagents that are sometimes toxic, the preservation of the environment is favored as no polluting residues are discharged into the atmosphere or into the drains; in this sense, the care of the health of the students is also ensured by not being in contact with said materials [11].

Simulators: Simulation is a numerical technique that, by modeling real systems, allows imitating the behavior of variables and their interrelationships, to understand internal processes and modify them if necessary.

A simulator is a machine that reproduces the behavior of a system under certain conditions. Simulators usually combine mechanical or electronic parts and virtual parts that help simulate reality, therefore, they can be used in the professional field for the training of people who will have a great responsibility in their charge, since their possible errors would put in risk the life of third parties or the functionality of highly expensive equipment. Thanks to the simulator, students can train until they acquire the experience and skills necessary to perform professionally. If they make mistakes in a simulator, nothing will go wrong [10][11].

According to [4], the requirements for the GUI of a virtual laboratory are: the creation of a friendly graphical environment, the complete visualization of the virtual experiment, instant feedback, degree of interactivity, programming language, single or multiple windows, platform and mode of execution, in such a way that the learning designed in the laboratory guides is fulfilled.

III. Methodology

To respond to the research objectives, 2 phases have been considered:

<u>First phase</u>: Characterization of the elements of the investigation, which includes:

The sample – Detailed in Table I, is made up of students from two universities, the URP- School of Mechatronics Engineering, as well as the UNTELS- School of Electrical Mechanical Engineering, enrolled in the corresponding courses and cycles.

TABLE I
STUDENTS BY CYCLE, SUBJECTS AND ACADEMIC SEMESTER

Semesters	URP		UNTELS	
	I - Cycle	VI-Cycle	I - Cycle	VI-Cycle
	Subjects			
	BMEW	EM	FIEME	EI
2020-I	29	18	39	53
2020-II	18	15	46	29
2021-I	23	18	48	37
2021-II	19	12	58	32
Total	89	63	191	151

Note: Basic Mechatronics Engineering Workshop (BMEW), Electric machines (EM), Fundamentals of Electrical Mechanical Engineering (FEME), Electrical Installations (EI)

Table I shows that in the URP the number of students in each subject and each semester is on average 50% less than in the UNTELS, this variable being very important for the evaluation of practical learning in virtual laboratories (VL) reason for our investigation.

a. Platforms used: It is detailed in Table II. According to the virtual education policies of each university.

In Peru, virtual education for the 2020-I school year was implemented through the use of computer tools, starting with a very limited offer of digital platforms as a solution to virtual classes, which were improved in the other semesters.

TABLE II
DIGITALS PLATAFORMS BY UNIVERSITY

Plataforms (video conference)	URP	UNTELS
Google Meet		x
Blackboard collaborate ultra	x	
Moodle-AV		x
Others	x	x

At the beginning of the pandemic, the URP already had its platform that was only used as a virtual classroom to post assignments, educational material, and tasks for asynchronous activities. UNTELS only had its virtual classroom in Moodle.

b. Computer equipment and connectivity: It is detailed in Table III. Both the availability and the type of resource and connectivity of the students to receive the classes. One table per university.

TABLE III
PERCENTAGE OF STUDENTS BY TYPE OF COMPUTER AND CONNECTIVITY

Semesters	URP							
	Type of computer equipment (%)				Connectivity type (%)			
	PC	Laptop	cell phone	Other	Total %	Optical fiber	WiFI	Data	Total %
2020-I	30	45	18	7	100	25	70	5	100
2020-II	30	52	13	5	100	30	65	5	100
2021-I	30	63	5	2	100	65	30	5	100
2021-II	25	72	3	0	100	65	35	0	100

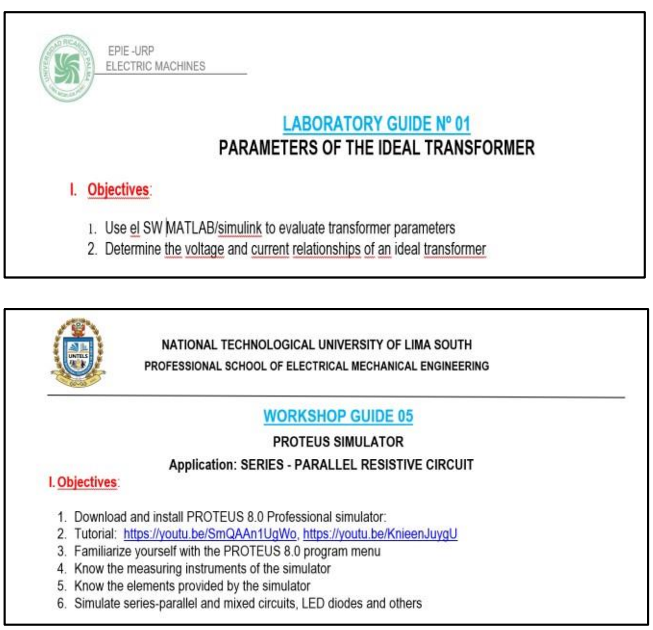
Semesters	UNTELS								
	Type of computer equipment (%)					Connectivity type (%)			
	PC	Laptop	Cell phone	Other	Total %	Optical fiber	WiFI	Data	Total %
2020-I	20	25	45	10	100	10	60	30	100
2020-II	20	45	30	5	100	15	60	25	100
2021-I	20	60	18	2	100	20	70	10	100
2021-II	25	69	6	0	100	25	73	2	100

Note: PC- desktop computer, Other= cell phone and Tablet

At the beginning of each semester, students were surveyed regarding the availability and type of computer equipment, as well as the type of connectivity for the development of their classes.

Regarding the computer equipment that includes a camera and microphone, in the 2020-I semester a great deficiency was found regarding the availability of technological resources, Table III shows us that in the URP an average of 75% of students had a computer and in UNTELS only 45% had computers; Regarding connectivity in the URP, an average of 70% had WI FI, while in the UNTELS, 30% consumed data from their cell phones for virtual classes, an analysis variable for the results of the investigation.

c. Laboratory and/or workshop guides: Figure 1 shows the format of the guides prepared by the responsible professor and according to university policies.


EPIE -URP
ELECTRIC MACHINES

LABORATORY GUIDE Nº 01
PARAMETERS OF THE IDEAL TRANSFORMER

I. Objectives:

1. Use el SW MATLAB/simulink to evaluate transformer parameters
2. Determine the voltage and current relationships of an ideal transformer

NATIONAL TECHNOLOGICAL UNIVERSITY OF LIMA SOUTH
PROFESSIONAL SCHOOL OF ELECTRICAL MECHANICAL ENGINEERING

WORKSHOP GUIDE 05
PROTEUS SIMULATOR
Application: SERIES - PARALLEL RESISTIVE CIRCUIT

I. Objectives:

1. Download and install PROTEUS 8.0 Professional simulator:
2. Tutorial: https://youtu.be/SmQAAn1UgWo, https://youtu.be/KnieenJuygU
3. Familiarize yourself with the PROTEUS 8.0 program menu
4. Know the measuring instruments of the simulator
5. Know the elements provided by the simulator
6. Simulate series-parallel and mixed circuits, LED diodes and others

Figure 1 Formats of the URP-UNTELS Laboratory and/or Workshop Guides

It contains: Guide number, laboratory and/or workshop title, objectives, theoretical framework, simulation development, results, conclusions and bibliography. The objectives define the type of software to be used, which must be installed on the computers on the first day of class to validate the theoretical concepts and simulate the solution of engineering problems.

d. Software by university, cycle and subject: It is detailed in Table IV.

It is important to consider that the URP has licensed software which is shared by OFISIC with the students, as long as the computer has the resources for these programs, while the UNTELS works with free software that is installed by the students themselves.

TABLE IV
SOFTWARE FOR VIRTUAL LABORATORIES BY CYCLES AND SUBJECTS

Software	URP		UNTELS	
	I - Cycle	VI-Cycle	I - Cycle	VI-Cycle
	Subjects			
	BMEW	EM	FEME	EI
MATLAB		X		
Multisim		X		
AutoCAD				X
Proteus	X	X	X	
Thinker cad	x		x	
Solidworks		x		x
MS OFICCE	x	x	x	x
Others	x	x	x	x

Note: Others- Ms Proyect, SPSS, visual C.

To efficiently develop the simulations of each of the laboratories, it is necessary that the computer equipment have a minimum of hardware requirements (HW).

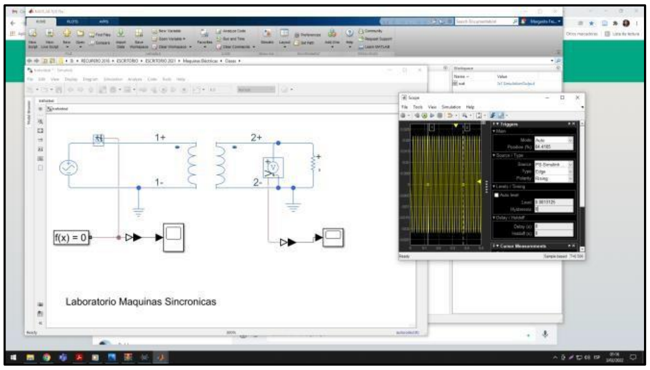
TABLE V
HARDWARE REQUIREMENTS FOR VIRTUAL LABORATORIES

Software	Hardware Requirements
MATLAB / simulink	***Processor** : Intel or AMD x86-64 with AVX2 instruction support. Disk: 2 GB for MATLAB only, 4-6 GB for a typical installation. **RAM** : 1GB minimum, 4GB recommended. **Graphics Card:** OpenGL 3.3 support recommended with 1GB GPU.*
AutoCAD	Compatible operating systems. • Microsoft® Windows® 7 SP1 (32-bit and 64-bit). Explorer.• Chrome. Minimum 1 gigahertz (GHz) 32-bit (x 86) **processor.** 64-bit processor. Basic. **Hardware. Memory** 6.0GB. Pointing device.Microsoft compatible mouse.
Proteus	**Proteus 8.9** for Windows, 32-bit and 64-bit compatible. OS: Windows XP SP3. **Processor**: 1.8 GHz. **Memory:** 3 GB of RAM. Graphics: Intel HD Graphics Card 3000. **Hard Drive**: 100MB free space.
Solidworks	CPU **processor**: 3.3 GHz or higher. **RAM memory**: 16 GB or more. GPU **graphics card:** use certified video cards, which are NVIDIA Quadro and AMD Radeon Pro WX. Hard drive: SSD.

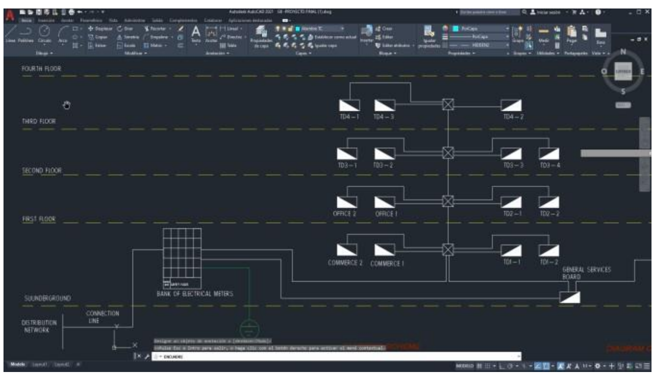
** Technical specifications of the programs

Due to the HW requirements shown in Table V, it is very difficult to use cell phones to simulate the problems of the laboratory guides.

Figure 2 shows us some screenshots of the virtual laboratories using the software specified in the guides, which need to be installed on a computer in order to simulate and obtain answers to engineering problems.



(a)



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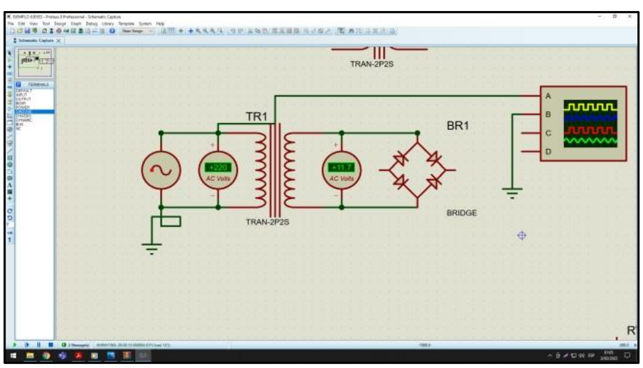


(c)

Figure 2 Most used software platforms: a. MatLAB b. AutoCAD c. Proteus

Second phase: Practical learning results, includes the following:

a. Application of a questionnaire with a Likert scale, to collect the opinion of the students. It consists of 12 questions regarding the computer equipment, the laboratory software-guides and the practical learning achieved at the end of each academic cycle.

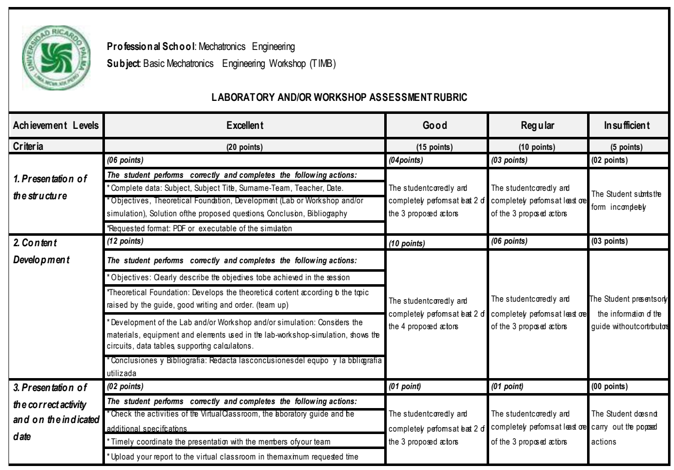
Table VI shows, as an example, a part of the database of the applied questionnaire, which includes the name of the subject, cycle, semester, sex and age of the sample.

TABLE VI
DATABASE OF THE QUESTIONNAIRE APPLIED

Study sample	Subjects	Cycle	Semester	Age	Sex	Questions 1	2	3	4	5	6	7	8	9	10	11	12
1	TIMB	I	2020-I	19	M	1	1	3	1	4	4	4	3	4	3	3	4
2	TIMB	I	2020-I	20	M	4	3	3	1	5	5	4	5	5	4	3	5
3	TIMB	I	2020-I	18	M	3	3	3	1	3	4	4	4	5	4	3	4
4	TIMB	I	2020-I	25	M	3	2	3	1	5	4	4	4	4	5	4	4
5	TIMB	I	2020-I	19	F	3	3	4	1	4	5	3	5	5	4	3	4
6	TIMB	I	2020-I	25	M	4	3	4	1	5	3	4	3	4	4	4	5
7	TIMB	I	2020-I	19	M	1	2	1	1	3	5	4	4	5	4	3	5

Note: Likert scale: 1= Definitely NO, 2= Probably NO, 3= Undecided, 4= Probably Yes, 5= Definitely Yes. M=male F=female

b. Analysis of evaluations: formative, summative and diagnostic, using the Rubric for the results of the achievement of practical learning in virtual laboratories.

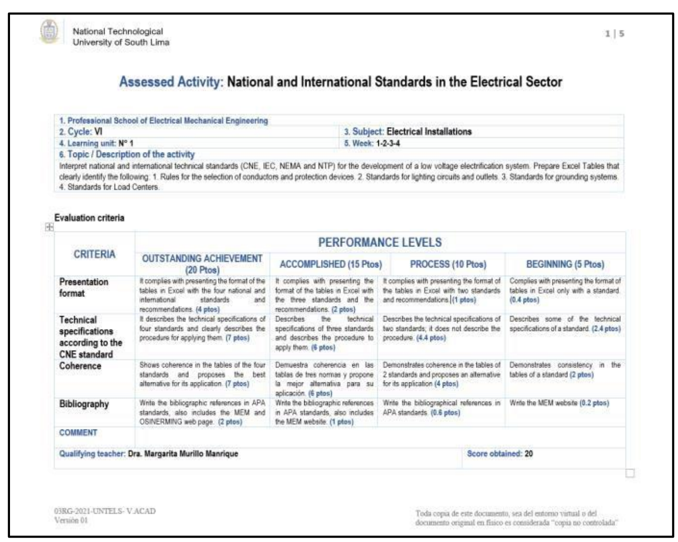


Professional School: Mechatronics Engineering
Subject: Basic Mechatronics Engineering Workshop (TIMB)

LABORATORY AND/OR WORKSHOP ASSESSMENT RUBRIC

Achievement Levels	Excellent	Good	Regular	Insufficient
Criteria	(20 points)	(15 points)	(10 points)	(5 points)
1. Presentation of the structure	(06 points) The student performs correctly and completes the following actions: * Complete data: Subject, Subject Title, Surname-Team, Teacher, Date. * Objectives, Theoretical Foundation, Development (Lab or Workshop and/or simulation), Solution of the proposed questions, Conclusion, Bibliography *Requested format: PDF or executable of the simulation	(04points) The student correctly and completely performs at least 2 of the 3 proposed actions	(03 points) The student correctly and completely performs at least one of the 3 proposed actions	(02 points) The Student submits the form incompletely
2. Content Development	(12 points) The student performs correctly and completes the following actions: * Objectives: Clearly describe the objectives to be achieved in the session *Theoretical Foundation: Develops the theoretical content according to the topic raised by the guide, good writing and order. (team up) * Development of the Lab and/or Workshop and/or simulation: Considers the materials, equipment and elements used in the lab-workshop-simulation, shows the circuits, data tables, supporting calculations. * Conclusiones y Bibliografia: Redacta las conclusiones del equipo y la bibliografia utilizada	(10 points) The student correctly and completely performs at least 2 of the 4 proposed actions	(06 points) The student correctly and completely performs at least one of the 3 proposed actions	(03 points) The Student presents only the information of the guide without contributions
3. Presentation of the correct activity and on the indicated date	(02 points) The student performs correctly and completes the following actions: * Check the activities of the Virtual Classroom, the laboratory guide and the additional specifications * Timely coordinate the presentation with the members of your team * Upload your report to the virtual classroom in the maximum requested time	(01 point) The student correctly and completely performs at least 2 of the 3 proposed actions	(01 point) The student correctly and completely performs at least one of the 3 proposed actions	(00 points) The Student does not carry out the proposed actions

(a)



National Technological University of South Lima

1 | 5

Assessed Activity: National and International Standards in the Electrical Sector

1. Professional School of Electrical Mechanical Engineering	
2. Cycle: VI	3. Subject: Electrical Installations
4. Learning unit: N° 1	5. Week: 1-2-3-4
6. Topic / Description of the activity	

Interpret national and international technical standards (CNE, IEC, NEMA and NTP) for the development of a low voltage electrification system. Prepare Excel Tables that clearly identify the following: 1. Rules for the selection of conductors and protection devices. 2. Standards for lighting circuits and outlets. 3. Standards for grounding systems. 4. Standards for Load Centers.

Evaluation criteria

CRITERIA	PERFORMANCE LEVELS OUTSTANDING ACHIEVEMENT (20 Ptos)	ACCOMPLISHED (15 Ptos)	PROCESS (10 Ptos)	BEGINNING (5 Ptos)
Presentation format	It complies with presenting the format of the tables in Excel with the four national and international standards and recommendations. (4 ptos)	It complies with presenting the format of the tables in Excel with the three standards and the recommendations. (2 ptos)	It complies with presenting the format of the tables in Excel with two standards and recommendations. (1 ptos)	Complies with presenting the format of tables in Excel only with a standard. (0.4 ptos)
Technical specifications according to the CNE standard	It describes the technical specifications of four standards and clearly describes the procedure for applying them. (7 ptos)	Describes the technical specifications of three standards and describes the procedure to apply them. (6 ptos)	Describes the technical specifications of two standards; it does not describe the procedure. (4.4 ptos)	Describes some of the technical specifications of a standard. (2.4 ptos)
Coherence	Shows coherence in the tables of the four standards and proposes the best alternative for its application. (7 ptos)	Demuestra coherencia en las tablas de tres normas y propone la mejor alternativa para su aplicación. (6 ptos)	Demonstrates coherence in the tables of 2 standards and proposes an alternative for its application (4 ptos)	Demonstrates consistency in the tables of a standard (2 ptos)
Bibliography	Write the bibliographic references in APA standards, also includes the MEM and OSINERMING web page. (2 ptos)	Write the bibliographic references in APA standards, also includes the MEM website. (1 ptos)	Write the bibliographical references in APA standards. (0.6 ptos)	Write the MEM website (0.2 ptos)
COMMENT				

Qualifying teacher: Dra. Margarita Murillo Manrique — Score obtained: 20

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(b)

Figure 2 Formats of the Evaluation Rubrics: a. URP b. UNTELS

Figure 2, presents the formats of the rubric for each university, each one describing the levels of achievement and the criteria for evaluating learning, both for synchronous (video conference) and asynchronous classes.

IV. Results

From Table I and Table VI, the characterization of the URP and UNTELS samples has been obtained. The information considers the four academic semesters of virtual classes, the subject, age and gender. These results are shown in Table VII.

TABLE VII

URP – Sample Per Semester According to Age and Sex

Semester	Age	Frecuency	Sex M	Sex F
2020-1	18-20	14	13	1
	21-25	12	12	0
	25 or more	3	3	0
2020-2	18-20	12	12	0
	21-25	6	6	0
	25 or more	0	0	0
2021-1	18-20	13	13	0
	21-25	8	8	0
	25 or more	2	2	0
2021-2	18-20	11	10	1
	21-25	8	8	0
	25 or more	0	0	0

a. BMEW-I-cycle

Semester	Age	Frecuency	Sex M	Sex F
2020-1	20-22	6	6	0
	23-25	9	9	0
	25 or more	3	3	0
2020-2	20-22	5	5	0
	23-25	7	7	0
	25 or more	3	3	0
2021-1	20-22	3	3	0
	23-25	10	10	1
	25 or more	5	5	0
2021-2	20-22	7	7	0
	23-25	4	4	0
	25 or more	1	1	0

b. EM E-VI-cycle

TABLE VII

UNTELS – Sample Per Semester According to Age and Sex

Semester	Age	Frecuency	Sex M	Sex F
2020-1	18-20	14	12	2
	21-25	23	22	1
	25 or mores	2	3	0
2020-2	18-20	16	16	0
	21-25	24	24	0
	25 or more	6	6	0
2021-1	18-20	21	20	1
	21-25	19	19	0
	25 or more	8	8	0
2021-2	18-20	22	22	0
	21-25	29	29	0
	25 or more	7	7	0

a. FEME-I-cycle

Semestre	Edad	Frecuencia	Sexo M	Sexo F
2020-1	20-22	15	12	3
	23-25	31	31	0
	25 or more	7	7	0
2020-2	20-22	11	11	0
	23-25	10	10	0
	25 or more	8	8	0
2021-1	20-22	11	13	0
	23-25	21	8	0
	25 or more	7	2	0
2021-2	20-22	9	8	1
	23-25	15	15	0
	25 or more	8	8	0

b. EI-VI-cycle

Tables VII show us that for the first cycle the age range with the highest percentage comprises the interval from 18 to 25 years. It should be noted that in the URP during the 4 semesters there have only been 2 women, while in the UNTELS there have been 4 women. For the sixth cycle, the age range with a high percentage is between 23 and 25 years old, highlighting that the URP has only had one woman, while in the UNTELS, 4 women were enrolled.

From the questionnaire:

The statistical results of the databases have been evaluated according to university, subjects, academic periods and indicators, according to the Likert scale.

For the URP: BMEW subject of the first cycle, indicators: computer equipment, software-guides of laboratory and learning, are shown in Tables: VIII-VIX and X**.**

Table VIII shows us that for the BMEW subject in 2020, at the URP, 52% of the students responded that they did not have computer equipment or that their equipment was not sufficient to develop the VL; for the second year 2021, 52% responded that, if they had computer equipment and that, if they were sufficient for the VL, however, the percentage of undecided that did not decrease in 2021 by only 3%.

TABLE VIII

URP – Availability of Computer Equipment -BMEW

Indicator	Semester	Scale	Frequency	Percentage
Computer equipment	2020	Definitely not	7	24
		Probably not	8	28
		Undecided	5	17
		Probably yes	4	14
		Definitely yes	5	17
	2021	Definitely not	5	17
		Probably not	5	17
		Undecided	4	14
		Probably yes	8	28
		Definitely yes	7	24

Note: BMEW (Basic Mechatronics Engineering Workshop) I cycle

TABLE IX

URP – Availability of Software and Laboratory- BMEW

Indicator	Semester	Scale	Frequency	Percentage
Software and Lab Guides.	2020	Definitely not	2	7
		Probably not	5	17
		Probably yes	9	31
		Definitely yes	8	28
	2021	Definitely not	2	7
		Probably not	4	14
		Undecided	4	14
		Probably yes	11	38
		Definitely yes	8	28

Note: BMEW (Basic Mechatronics Engineering Workshop) I cycle

Table III shows us the types of computer equipment and levels of connectivity, these results support the high percentage of positive responses about the software Table IX, it is also due to the fact that the Faculty of Engineering-URP is nationally and internationally accredited, so it has licensed software, which is shared with students.

TABLE X

URP – Learning Outcomes- BMEW

Indicator	Semester	Scale	Frequency	Percentage
Learnings	2020	Definitely not	6	20.7
		Probably not	6	20.7
		Undecided	4	13.8
		Probably yes	6	20.7
		Definitely yes	7	24.1
	2021	Definitely not	4	13.8
		Probably not	5	17.2
		Undecided	4	13.8
		Probably yes	8	27.6
		Definitely yes	8	27.6

Note: BMEW (Basic Mechatronics Engineering Workshop) I cycle

Table X shows us that for the BMEW subject of the URP in the year 2020, 41.7% of the students consider that, if they achieved practical learning in VL, while for the year 2021 the percentage of achievement of learning increased to 55.2%, indicating that the VL allowed them to simulate the solution of real engineering problems.

For the URP: EM subject of the sixth cycle, indicators: computer equipment, software-laboratory guides and learning, are shown in Tables: XI- XII and XIII.

TABLE XI
URP – AVAILABILITY OF COMPUTER EQUIPMENT- EM

Indicator	Semester	Scale	Frequency	Percentage
Computer equipment	2020	Definitely not	2	11.1
		Probably not	2	11.1
		Undecided	3	16.7
		Probably yes	6	33.3
		Definitely yes	5	27.8
	2021	Definitely not	2	11.1
		Probably not	4	22.2
		Undecided	3	16.7
		Probably yes	4	22.2
		Definitely yes	5	27.8

Note: EM (Electric Machines) VI cycle

In 2020, 61.1% of students had computer equipment and very good HW capabilities. In 2021 the percentage dropped to 51%, the accusations according to their comments were due to the fact that they shared equipment with their brothers or that the machine had faults.

TABLE XII
URP - AVAILABILITY OF SOFTWARE AND LABORATORY- EM

Indicator	Semester	Scale	Frequency	Percentage
Software and Lab Guides.	2020	Definitely not	2	11.1
		Probably not	5	27.8
		Undecided	3	16.7
		Probably yes	4	22.2
		Definitely yes	4	22.2
	2021	Definitely not	2	11.1
		Probably not	4	22.2
		Undecided	2	11.1
		Probably yes	6	33.3
		Definitely yes	4	22.2

Note: ME (Electric Machines) VI cycle

Regarding software (SW) and laboratory guides in 2020, 44.4% of students had SW licensed according to the requirements of the guide, in 2021 the percentage rose to 55.5%, due to the fact that the URP in a mandatory way through of the teacher shared the licensed SW with the students, Table XII.

TABLE XIII
URP – LEARNING OUTCOMES-ME

Indicator	Semester	Scale	Frequency	Percentage
Learnings	2020	Definitely not	3	16.7
		Probably not	4	22.2
		Undecided	2	11.1
		Probably yes	5	27.8
		Definitely yes	4	22.2
	2021	Definitely not	1	5.6
		Probably not	3	16.7
		Undecided	2	11.1
		Probably yes	7	38.9
		Definitely yes	5	27.8

Note: EM (Electric Machines) VI cycle

Table XIII shows in 2020, 48% of students responded that they had achieved a good level of practical learning in VL, as well as in 2021, 66.7% indicated satisfaction with their learning.

For UNTELS: FEME subject of the first cycle, indicators: computer equipment, software-guides of laboratory and learning, are shown in Tables: XIV-XV and XVI.

TABLE XIV
UNTELS- AVAILABILITY OF COMPUTER EQUIPMENT-FEME

Indicator	Semester	Scale	Frequency	Percentage
Computer equipment	2020	Definitely not	22	47.8
		Probably not	17	37.0
		Undecided	5	10.9
		Probably yes	2	4.3
		Definitely yes	0	0.0
	2021	Definitely not	5	17.2
		Probably not	5	17.2
		Undecided	4	13.8
		Probably yes	8	27.6
		Definitely yes	7	24.1

Note: FEME (Fundamentals of Electrical Mechanical Engineering), I cycle

At the beginning of the pandemic in 2020, 84.8% of students in the first cycle did not have computer equipment and if they had it was not enough to run a SW, only 15.2% had operating equipment. By 2021, the percentage of students with computer availability rose to 51.7%.

TABLE XV
UNTELS - AVAILABILITY OF SOFTWARE AND LABORATORY-FEME

Indicador	Semestre	Escala	Frecuencia	Porcentaje
Software and Lab Guides.	2020	Definitely not	30	65.2
		Probably not	12	26.1
		Undecided	2	4.3
		Probably yes	1	2.2
		Definitely yes	1	2.2
	2021	Definitely not	2	6.9
		Probably not	4	13.8
		Undecided	4	13.8
		Probably yes	11	37.9
		Definitely yes	8	27.6

Note: FEME (Fundamentals of Electrical Mechanical Engineering), I cycle

Regarding the availability of software in 2020, 91.3% had no knowledge, while by 2021 65.5% were already using free SW according to the capacity of their equipment, table XV.

TABLE XVI
UNTELS – LEARNING OUTCOMES-FEME

Indicator	Semester	Scale	Frequency	Percentage
Learnings	2020	Definitely not	5	10.9
		Probably not	6	13.0
		Undecided	7	15.2
		Probably yes	10	21.7
		Definitely yes	18	39.1
	2021	Definitely not	4	13.8
		Probably not	5	17.2
		Undecided	4	13.8
		Probably yes	8	27.6
		Definitely yes	8	27.6

Note: FEME (Fundamentals of Electrical Mechanical Engineering), I cycle

Regarding the learning results in 2020, 60.8% responded positively, while in 2021 only 55.2% indicated that they had achieved good learning, this is because the students have a low level in computer science, table XVI

For the UNTELS: EI subject of the sixth cycle, indicators: computer equipment, software-guides of laboratory and learning, are shown in Tables: XVII-XVIII and XIX.

TABLE XVII
UNTELS - AVAILABILITY OF COMPUTER EQUIPMENT-EI

Indicator	Semester	Scale	Frequency	Percentage
Computer equipment	2020	Definitely not	12	26.1
		Probably not	8	17.4
		Undecided	5	10.9
		Probably yes	10	21.7
		Definitely yes	11	23.9
	2021	Definitely not	0	0.0
		Probably not	5	10.9
		Undecided	8	17.4
		Probably yes	18	39.1
		Definitely yes	15	32.6

Note: EI (Electrical Installations), VI cycle

In 2020, 45.6% of sixth cycle students had equipment, in 2021 the availability of equipment with a good level of HW improved by 27.1%, table XVII

TABLE XVIII
UNTELS - AVAILABILITY OF SOFTWARE AND LABORATORY-EI

Indicator	Semester	Scale	Frequency	Percentage
Software and Lab Guides.	2020	Definitely not	5	10.9
		Probably not	6	13.0
		Undecided	7	15.2
		Probably yes	10	21.7
		Definitely yes	18	39.1
	2021	Definitely not	0	0.0
		Probably not	5	10.9
		Undecided	8	17.4
		Probably yes	18	39.1
		Definitely yes	15	32.6

Note: EI (Electrical Installations), VI cycle

Regarding the availability of SW, in 2020, 60.8% had free SW, while by 2021 it rose to 71.7% who installed SW for circuit simulations as specified in the laboratory guides, table XVIII.

TABLE XIX
UNTELS– LEARNING OUTCOMES-EI

Indicator	Semester	Scale	Frequency	Percentage
Learnings	2020	Definitely not	8	17.4
		Probably not	10	21.7
		Undecided	5	10.9
		Probably yes	12	26.1
		Definitely yes	11	23.9
	2021	Definitely not	0	0.0
		Probably not	4	8.7
		Undecided	8	17.4
		Probably yes	15	32.6
		Definitely yes	19	41.3

Note: EI (Electrical Installations), VI cycle

Regarding the learning results in 2020, 49% responded positively, while in 2021, 73.9% indicated that they had achieved a good learning level, including some comments that they had learned more than in face-to-face classes, table XIX.

From the rubric:

The application of the rubric to evaluate competencies during the two years of the pandemic allowed us to obtain learning results according to the marks obtained in the evaluations: diagnostic, formative and summative. Figure 3 shows the data obtained according to the rubric formats and evaluation formulas of each university.

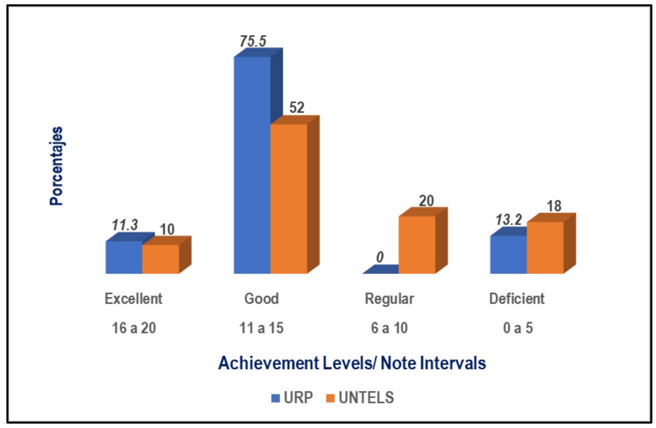

Fig. 3 Indicators considered to evaluate the results of the practical learning through a Rubrics
Note: Applies for each subject per semester and per university

The statistical evaluation shows us the results in Figures 4 to 6, with the levels of achievement, by subjects, semester and by university.

From Figure 4 it can be concluded that the highest percentage in the excellent level was obtained in the period 2021-I with 39% and, the poor level in 2020-I with 25% of students, some withdrew before to end the cycle.

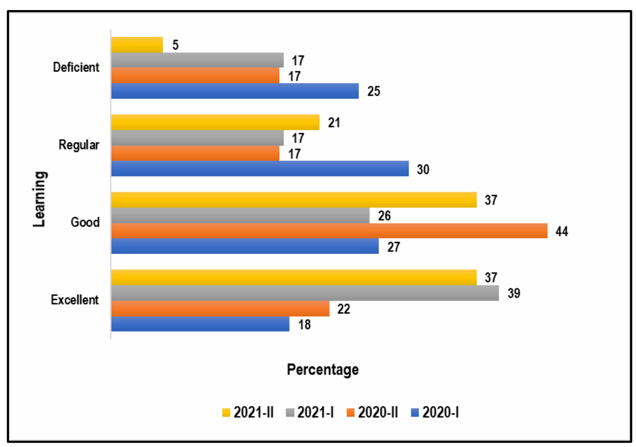

Fig. 4 URP- Learning Outcomes according to rubric
Note: BMEW (Basic Mechatronics Engineering Workshop) I cycle

From Figure 5 it is observed that in the period 2021-I 11% achieved an excellent level, however, in 2020-I 20% of students had a poor level, many withdrew before the end of the cycle. It is noteworthy that in the 2021-I semester, 78% obtained a good level, this is because the students already had programming knowledge.

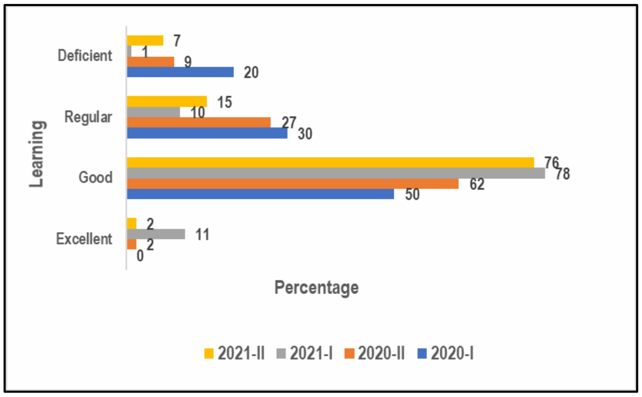

Fig. 5 URP-Learning Outcomes according to rubric
Note: EM (Electric Machines), VI cycle

From Figure 6 show significant values in the level achieved, obtaining in the period 2021-II 70% being students of the first cycle, however, high percentages are observed in the levels in process and beginning.

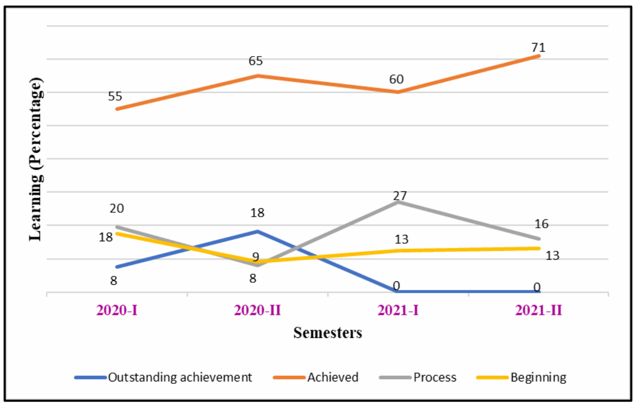

Fig. 6 UNTELS-Learning Outcomes according to rubric
Note: FEME (Fundamentals of Electrical Mechanical Engineering) I-cycle

From Figure 7 show significant learning values of sixth cycle students, in the 2021-I semester 22% are at the outstanding achievement level and in the 2021-II period 80% are at the achieved level, at this level, high percentages obtained according to the criteria of the rubric are observed.

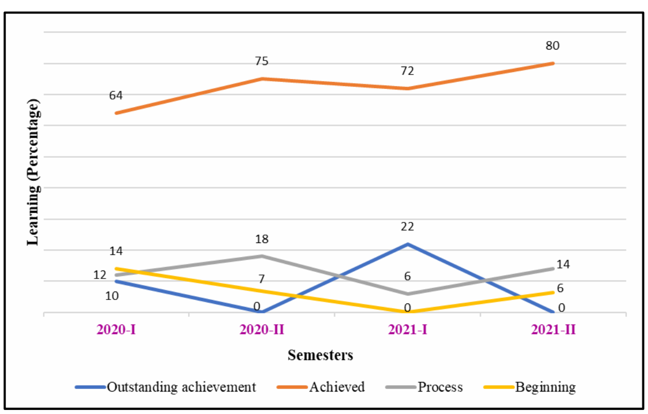

Fig. 7 UNTELS-Learning Outcomes according to rubric
Note: EI (Electrical installations) VI cycle

V. Conclusions

The data obtained from the different indicators investigated, allows us to conclude that:

For first-cycle students who began their studies in 2020-I, the adaptation was slow to develop virtual laboratories, considering the lack of equipment, limited access to software and poor connectivity (UNTELS case), low computer skills , access to virtual classes from rural areas and some students working during class hours. However, in the URP and UNTELS, the learning levels from the perspective of the students themselves (questionnaire) and from the teacher's evaluation (rubric) in the different semesters record the good level in learning achievement.

For the sixth cycle students (URP and UNTELS), the adaptation was faster, considering that they had already been using some simulators as a complement to face-to-face laboratories, we added to this the ability of young people to interact with multimedia. At the URP he had already taken the programming subject, so the results show excellent levels and outstanding achievement of his learning. It is important to highlight that in the 2021-I cycle, the students published an article referring to VL in a specialty journal, as indicated by [13].

In both cases, the difficulties were greater in the 2020-I and II semesters, the number of students per class also has an influence, since the UNTELS in all semesters had 50% more students than the URP, Table I, reasons that influence the results of learning in the VL. It is also necessary to note that in both universities the percentage of women is minimal, table VI, which is of concern, so admissions departments are recommended to consider vocational campaigns in women's colleges.

Finally, the results obtained force us to pay special attention to those levels of regular, ongoing or deficient learning. The results in the first cycle are attributed to the weak development of the students' abilities during their school education, so a leveling cycle for the entrants should be previously considered. For the sixth cycle, it is recommended to develop the type of hypothetical-deductive thinking through research, encouraging the use of technology, forming teams that work in real time, that improve laboratory practices through simulations. At UNTELS, the results obtained are being used as information, to update the curricular structures and in detail the content and methodological strategies for the new normality, which we are already facing this year 2022 with blended classes and will soon return to face-to-face classes.

Acknowledgment

Recognition to the students of the URP and UNTELS who in these two years of pandemic demonstrated resilience, adapted to the changes in their learning process and are prepared for future challenges.

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