The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
Paper ID #41604

Remote Learning: A Means to Advance Educational Equity in Isolated or Rural Regions

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Remote Learning: A Means to Advance Educational Equity in Isolated or Rural Regions (Evaluation of Program/Curriculum)

1. Abstract

A significant disparity exists in the quality of education between urban and rural areas in Latin America. While urban centers and towns benefit from well-equipped schools staffed by qualified educators, facilitating effective teaching and learning, rural schools still face numerous challenges.

Despite a relatively high level of student engagement in the learning process at the elementary level in rural areas, there is a substantial exodus of students from the rural education system at the high school level. Sheer numbers and stark contrasts to the educational opportunities available in urban high schools mark this departure.

One possible factor contributing to students leaving these schools is the shortage of qualified subject-specific teachers capable of delivering high school-level content in a way that resonates with students.

Research on this issue suggests that there are several factors responsible for the challenges faced by the rural education system. Some of them:

1. Limited access to the didactic and pedagogical resources that urban areas enjoy.
2. Need for more familiarity with technology and its educational benefits.

The ongoing pilot project aims to investigate and develop a methodology to address the needs of rural schools. This methodology includes 1) providing well-prepared teachers through remote learning, 2) granting access to high-quality educational materials through a learning management system, and 3) implementing a hybrid learning approach that combines the expertise of urban teachers with the practical support of local educators.

The project has designed a condensed course focused on energy transformation and sustainability to assist rural students and educators in gaining knowledge about electricity and alternative energy sources. By the course's conclusion, participants should be capable of constructing a microgrid to ensure a stable supply of electrical Energy within their school.

The course is delivered remotely through a collaborative effort between an "urban" teacher called a remote instructor and the “rural” schoolteacher called in the paper local instructor. The course consists of eight synchronous weekly sessions, guided by the expert teacher via remote learning, with additional assistance from the local teacher. Following these sessions, students can access various asynchronous activities to supplement their understanding of the material covered in the live sessions. The final two sessions involve hands-on activities: 1) crafting a solar charger for mobile phones and 2) creating a model microgrid capable of providing electrical Energy to at least one classroom. Subsequently, students and teachers will present their achievements to the local community.

To evaluate the project's learning outcomes, students underwent pre- and post-tests focusing on the project's content. They also participated in a survey gauging their attitudes towards STEM subjects and careers. Additionally, the assessment involved a review of students' engagement with and completion of

asynchronous assignments, examining the influence on the learning process. In summary, the paper presents the findings and insights from these assessments and the project.

2. Literature review

According to the World Bank (2019) [1], the number of people without access to electricity supplies decreased from 1.2 billion in 2010 to 759 million in 2019. Electrification through decentralized solutions based on renewable Energy gained momentum. According to the same report, the number of people connected to isolated mini electrical grids (called microgrids) doubled between 2010 and 2019, going from 5 to 11 million people. However, there is still much to do. Through her presentation in TED talks, engineer Rose Mutiso (2019) [2] presents the problem and describes alternative solutions with the introduction of sustainable electricity production (wind and solar) in the same communities.

In Mexico, according to Energía Hoy (Servin, 2021) [3], there are more than 2 million people who lack access to electrical Energy. Maintaining these levels of inequalities of opportunities for those nonprivileged communities to have access to this source of Energy is forcing them to be second-class citizens. The same article presents that since 2017, the programs to provide electricity in rural areas have "completely disappeared." The solution proposed for this situation by some companies is the generation of Energy in the same population using solar panels and the local distribution of the Energy produced and stored.

Today, generating and storing electrical Energy in areas isolated from the electrical grid is a relatively simple and low-cost process. Have access to a lighting system that does not generate toxic gases, that allows children to read and study in the afternoons/nights, to be able to charge their cell phone and activate a tablet (activities that we take for granted in urban areas), is not a titanic challenge, but requires that the necessary information reach those communities so that they can organize and carry out their energy project. (Suri, 2020) [4]

This need opens the door to the opportunity to not only provide electricity to rural or remote communities but also to be able to use this process as a framework to develop and implement a teaching-learning model on the topics of Energy, Electricity, and Sustainability, where students and community members participate in an academic program. This academic program will allow them first to acquire the concepts and skills necessary to build a prototype solution, which includes a) Energy Conservation, b) Renewable and Non-Renewable Energy, c) Solar Energy, d) Fundamentals of Electricity, e) Fundamentals of Photovoltaic Cells, and f) Battery Energy Density; and then implement the construction of a micro-grid, based on what they have learned and explored during the implementation of the program.

The fact of the existence of the need to have access to reliable electrical Energy in rural populations, together with the experiences published in the literature, shows the feasibility of this type of intervention. The literature shows that the highest success rate of this type of project occurs in communities where its members are involved in developing and implementing independent electrical networks – micro-grid (Schnitzer, 2014; Suri, 2020) [4,5]. This situation offers an opportunity to use this need as a framework to reach these rural and remote communities with an educational methodology in which their young people can acquire the necessary knowledge to develop microgrids in their communities and learn remotely. (synchronously and asynchronously).

Given the geographical conditions of the audience (a school in a rural area to be designated), the educational process will be implemented remotely. This process will require the development of an educational model that allows flexible implementation and can evaluate the participants' educational progress, not only in content knowledge but also in the skills acquired.

The implementation of instruction through mixed media, synchronous and asynchronous (blended), provides a solution to one of the biggest problems of education in rural areas: access to teachers with the necessary knowledge (Ghimire, 2022) [6]. Next, the project will develop a Project Based Learning (PBL) unit to ensure the involvement and motivation of the participants. This PBL unit will include the contents and skills mentioned above. The PBL unit will include the STEM (Science, Technology, Engineering and Mathematics) approach. Many sources agree that PBL offers the possibility of bringing classroom activities closer to the students' experiences (both in-person and remote). This activity promotes the student's changes and the production of creative solutions based on their development and interaction with their context. (Bell,2010; Lucas Ed, 2020; Pereira, 2021; Xu, 2021; Parimala, 2022, Pertiwi, 2021) [7,8,9,10,11,12]. As expressed by Chu et al. (2017) [13]

> *"With the Project-Based Learning (PBL) approach, students explore issues, topics, or problems in depth without predefined answers. This allows them to engage in realistic and stimulating learning processes."*

The implementation of the project will not only be meeting a need, that of providing access to electrical Energy to nonprivileged communities, but, at the same time, it will be promoting skills and content in careers related to STEM to the members of said communities (young people in high school age and adults). The success of this project motivates young people in rural areas to remain interested and continue their education in these areas of knowledge. The exploration of the concepts of solar Energy, conversion to electricity, and the new possibilities in the more specialized labor market can awaken concerns in the participants that may lead them to want to study these topics in more depth and subsequently join the workforce in the STEM content areas.

Finally, developing a practical and tested teaching-learning methodology through remote education and PBL can generate a general and replicable model. This model will allow other necessary content to be brought to rural areas, ensuring that young people in rural communities have greater possibilities of equitable access to the resources we take for granted in urban areas. This last point is consistent with the vision of the **Instituto Politecnico Nacional (IPN)** of Mexico, the academic unit that supports this initiative.

Following is the description of the education blended model, its implementation via a pilot project, and the presentation of the results, findings, and conclusions of the project MicroGrid V 1.0

3. Implementation of the Project MicroGrid V 1.0 – Pilot

3.1 The educational model - Description

As shown above, many rural institutions need equitable access to the same resources as urban areas. To develop a potential strategy to mitigate these differences, the author embarked on a process to develop a systematic approach, a replicable remote educational model designed to minimize the impact of rurality and lack of access in these nonprivileged communities.

3.1.1 The agents that are participating in the model.

This educational model is based on providing a complete blended learning experience to the rural learning communities. It is composed of several agents and supported by Communication and Information Technologies (CIT). Here is the description of the agents participating in the educational model:

a) <u>The REMOTE INSTRUCTOR:</u> This agent is a qualified instructor to provide instruction in the content area and has access to a minimum CIT infrastructure and skills. As the name remote denotes, this instructor does not have to practice in the remote community. It can be ANY qualified instructor worldwide willing to participate in the learning activity.
b) <u>The LOCAL INSTRUCTOR:</u> This agent is an instructor based in a remote location. The task of the local instructor has two prongs: 1) organize the group of students and support them during the implementation of the blended learning experience, and 2) facilitate the logistics needs of the project on the site. The LOCAL
c) <u>The LOCAL INSTITUTION:</u> This agent facilitates the logistics needed for the project to run. These needs include: 1) Ensuring the immersion of the course of the project in one of the subjects students are graded and need to complete (the course of the project is NOT an extra load for the students and teachers), 2) assign and facilitate the participation of the local instructor in the project, 3) facilitate the minimum hardware materials as well as the CIT resources needed for the implementation of the blended strategy.

3.1.2 The instructional design

The project's instructional design is based on implementing a blended strategy. The blended strategy is composed of two different types of meetings: *synchronous* and *asynchronous meetings*.

In *synchronous meetings*, the remote instructor facilitates the topic through videoconference technology in collaboration with the local instructor. During these meetings, the remote instructor communicates directly with the students, while the local instructor supports the activities (and at the same time actualizes his/her knowledge on the topic). In order to make these meetings more dynamic and participative, the remote instructor uses CIT resources such as Menti – an interactive platform that facilitates the interaction of the students with the remote instructor using students' cellular phones. In remote locations, <u>the internet bandwidth is limited.</u> Using only ONE computer to implement the synchronous meeting (instead of each student connected to the videoconference) improves communication with the class, and the students' interactions via cell phones have no impact on the bandwidth. The remote instructor has access to the minimum CIT resources at the location where the instructor lives (cameras, microphones, tablet, board, laboratory equipment, and others) to allow the implementation of the class as the class is taking place at an IN-PERSON meeting and can be presented remotely to the remote location. On the other hand, the remote students can interact with the remote instructor like students sitting at the IN-PERSON session.

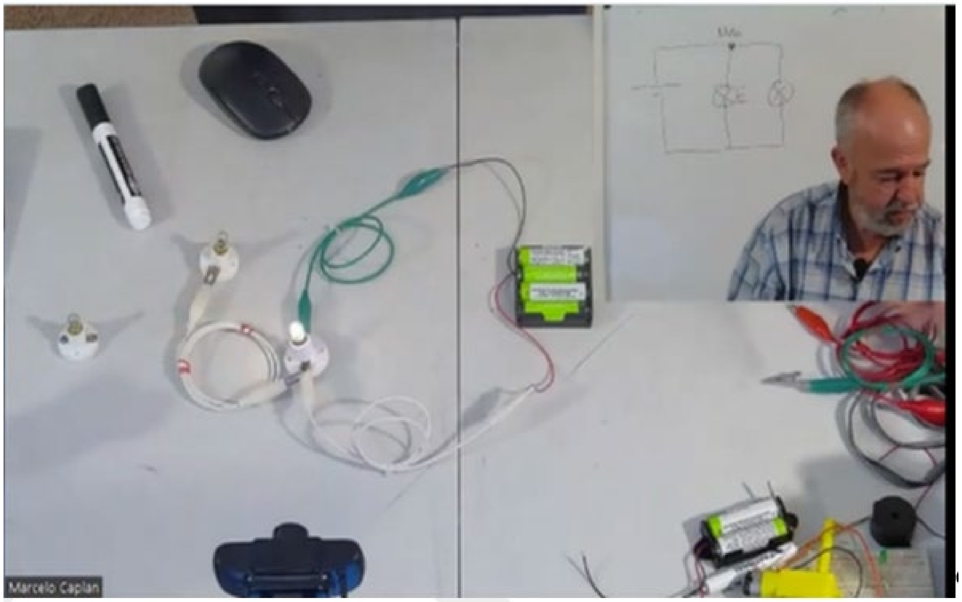

Figure 1. Image of a synchronous meeting: Remote instructor teaching.

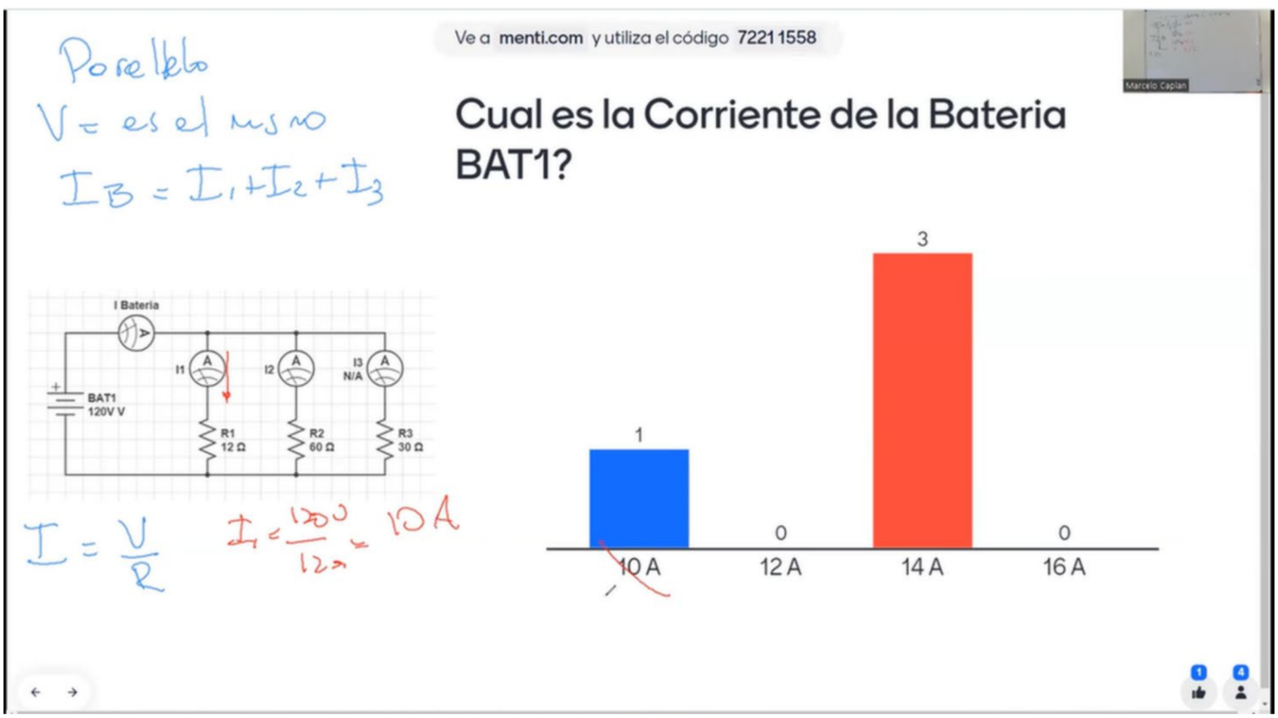

Figure 2. Using the application Menti to communicate between the remote instructor and the local classroom.

The *asynchronous meetings* are designed to facilitate the local instructor and her/his students' access to the materials covered during the synchronous meeting. The material is accessible using a Learning Management System (LMS). The project used the Canvas free for teachers LMS. Given the location of the remote schools, which are in several countries in Latin America, the primary language of the LMS was Spanish. Under the local instructor's leadership, students explore different activities designed to support the learning process.

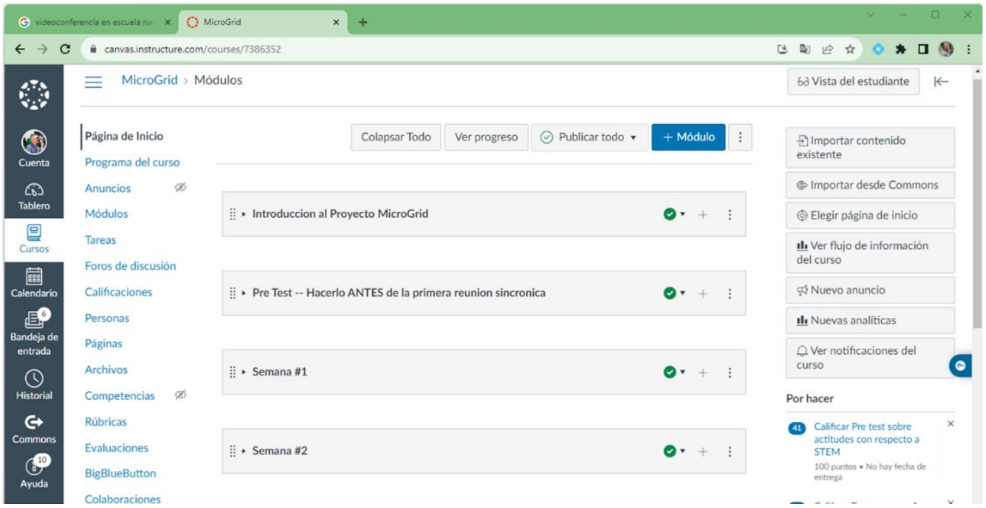

Figure 3. The Home page of Canvas LMS free for teacher course

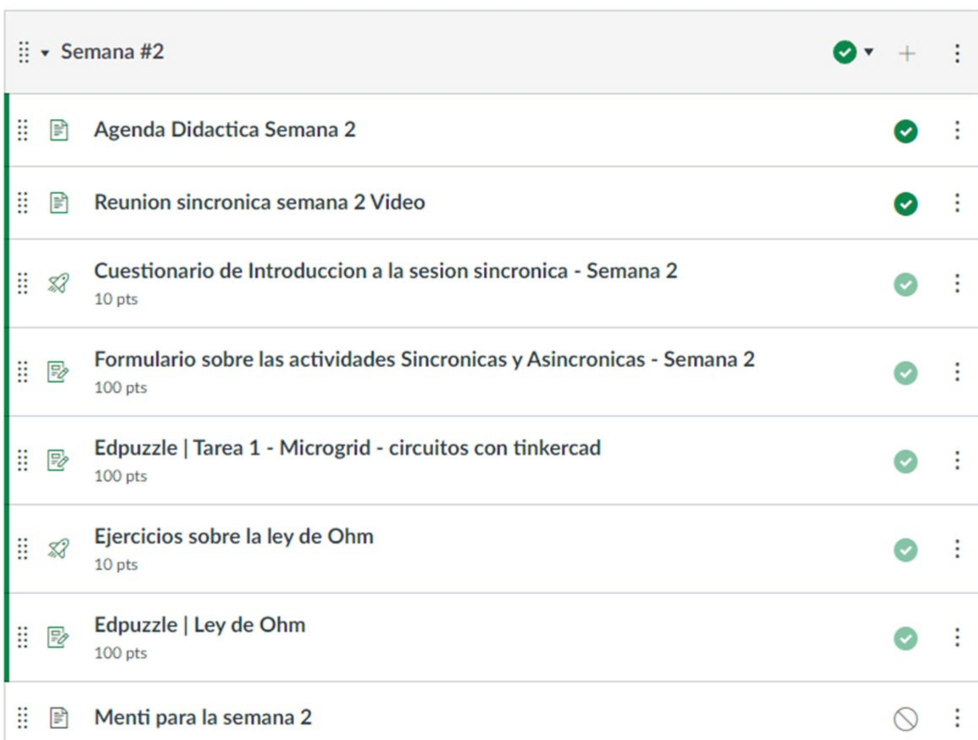

Figure 4. An example of the development of the content of a weekly meeting using the LMS

For many local instructors and their students, this is the first time they use an LMS in their learning experience. To facilitate navigation, the LMS is organized as a set of modules, each corresponding to a specific week in the course, as shown in Figure 4.

Each module includes a page called “Agenda Didactica Semana # X" (Didactic Agenda Week #X), where the student can find ALL the links and materials needed for the current week's meeting. Figure XX shows the general template of the didactic agenda.

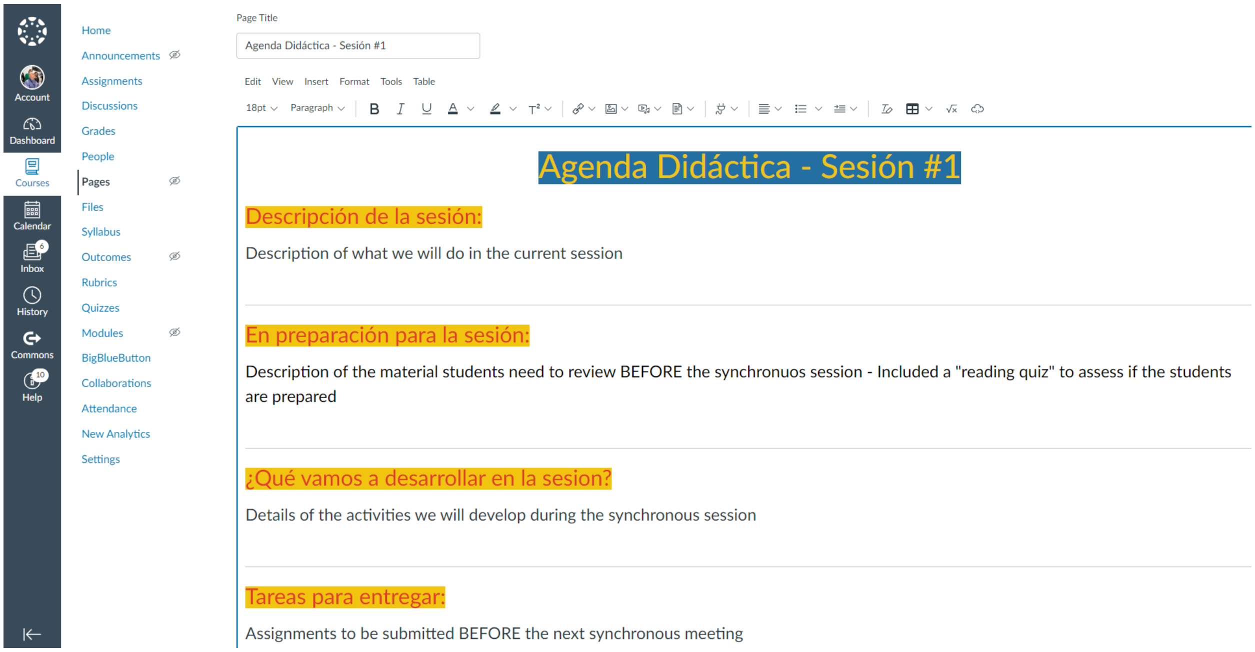

Figure 5. The general template of the Didactic Agenda Week # 1

<u>In preparation for the synchronous meeting, you need to:</u> Following the description of the session and what we will be learning during this synchronous meeting, there is the section - En preparacion para la actividad sincronica tienes que – (In preparation of the synchronous meeting you need to), where students receive instructions of which materials need to learn previous the meeting. These materials are presented in video format to make the interaction with the material more accessible for the students. Then, students must complete a quiz to assess if they have reviewed the material. These "reading quizzes" can be used by the local instructor at the time to assign a final grade to their students.

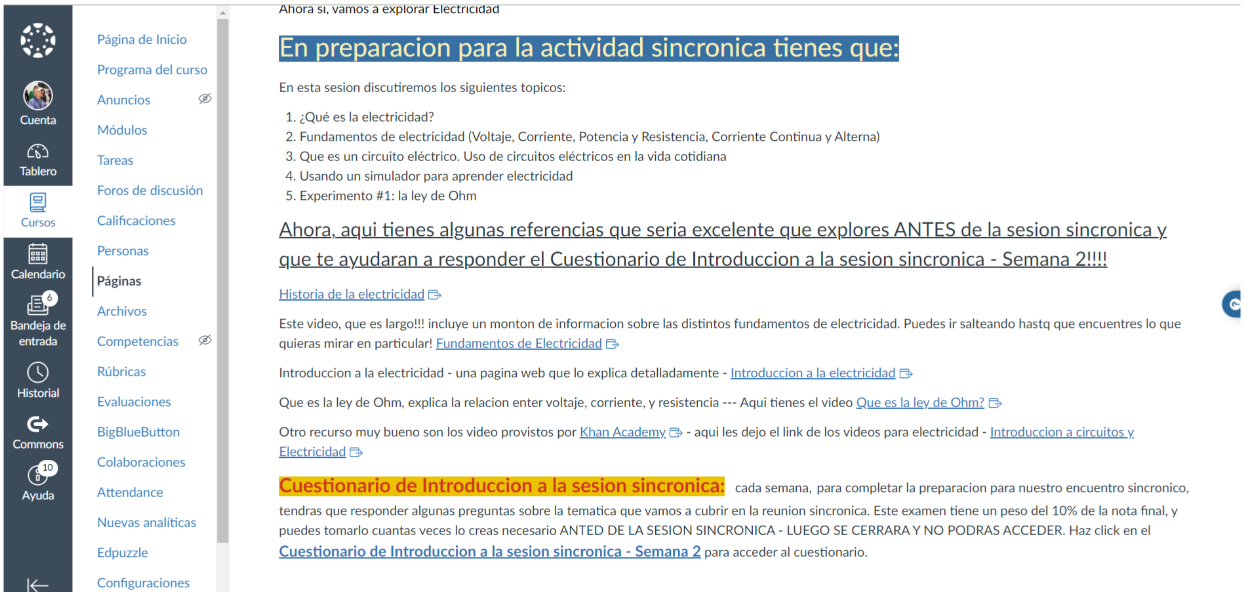

Figure 6. Example of the section of the LMS - In preparation for the synchronous meeting, you need to

<u>During the synchronous activity, we will:</u> this section of the Didactic Agenda – Durante la actividad sincronica vamos a: - includes a brief description of the topic we will cover during the synchronous meeting and the links to ALL the resources we will use in the meeting: access to simulations, material they need to have available, and more. Students can follow the remote instructor using the same resources simultaneously (if local conditions allow!)

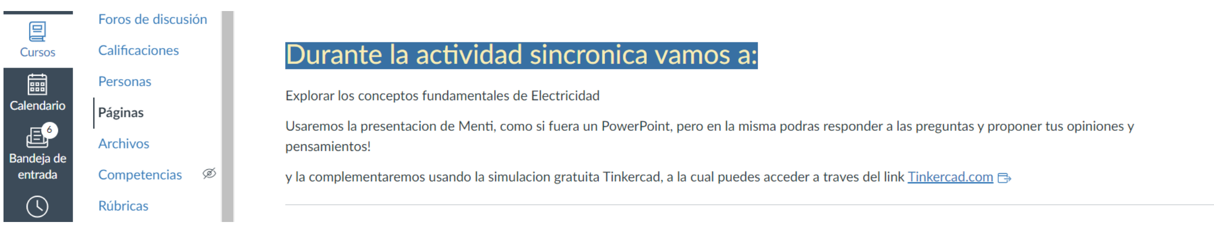

Figure 7. Example of the section of the LMS - During the synchronous activity, we will

<u>Assignments you need to submit BEFORE the next synchronous meeting</u>: this section of the Didactic Agenda - Las tareas que tienes que preparar ANTES de la proxima actividad sincronica son – include the links to all the assignments students need to perform, independently or under the tutelage of the local instructor before the next synchronous meeting. All these assignments are designed to be interactive to facilitate students' review and learning of the material presented at the synchronous meeting. They are composed of video quizzes where students must follow the videos, solve problems, collect data, and explore situations using simulations. The platform for these video quizzes is Edpuzzle, which interacts with Canvas LMS and facilitates the automatic grading of students' work. Also, as part of the assignments for each meeting, students complete a form regarding their impressions of the synchronous and asynchronous meeting – via Google Forms to ensure that the information will be anonymous.

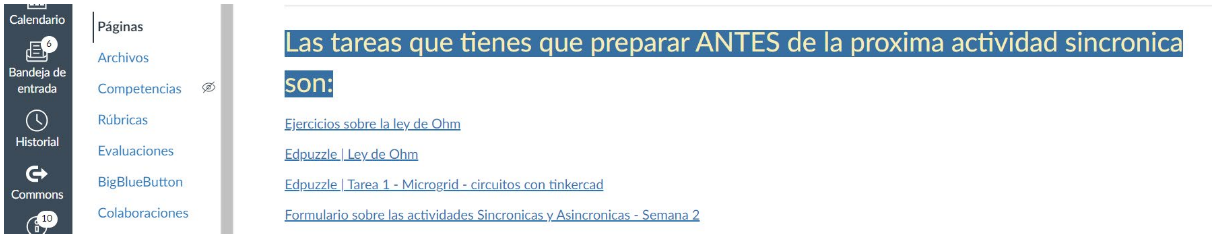

Figure 8. Here is an example of the LMS section where you need to submit your assignments BEFORE the next synchronous meeting.

3.1.3 Structure of the course

The course was designed to have eight synchronous sessions of two periods led by the remote instructor and asynchronous meetings led by the local instructor. Students were also encouraged to work independently.

During the synchronous meetings, students are exposed to the material and shown demonstrations and applications of the contents learned daily. Then, students will complement their learning experience by implementing the asynchronous assignments. In the synchronous meetings, students will implement and discuss experiments – collecting and analyzing actual data and working on their two projects on a mini microgrid to charge their phones and a large microgrid to power their classroom. The final meeting includes a final presentation (by groups) explaining how a microgrid works and the designed microgrid for their community.

Further information regarding the content of the course is available in the Didactic Sequence section.

3.1.4 The Didactic Sequence

The Didactic Sequence of this course is based on a previous work of the researcher, implementing similar content in a summer camp IN-PERSON with a similar audience in an urban setting (Caplan, 2018) [14]

The **general objective** of the course is to help students understand the importance of the concept of energy, how it is relevant to their daily lives, and how access to electrical energy is fundamental for the development of communities.

The **specific objectives**: At the end of the project, students will be able to

1) Understand how the concept of Energy is relevant in their daily life

2) Recognize and use basic electrical concepts to evaluate situations and solve problems

3) Measure electrical parameters through physical activities and simulations

4) Design, build, and evaluate a microgrid that can provide electrical Energy to a specific area of the school or community

Below is the description of the weekly content developed in the course.

Table 1. Didactic Sequence of the course

Week #1	Introduction: The problem of lack of access to electrical Energy in rural areas Introduction to the Concept of Energy Where Energy comes from – Renewable and non-renewable energies. Electrical Energy is a versatile and easy-to-transport energy source. What would your day be like if you did not have electricity?
Week #2	Introduction to Electricity What is electricity? Fundamentals of electricity (Voltage, Current, Power and Resistance, Direct and Alternating Current) What is an electrical circuit? Use of electrical circuits in everyday life Experiment #1: Ohm's Law
Week #3	How to build electrical circuits with more than one component – Series and parallel circuits – Fundamental laws of electricity – Kirchoff's laws Experiment #2: Corroborating Kirchoff's laws Using Kirchoff's laws to design a circuit with LEDs Construction of electrical circuits with LEDs
Week #4	Solar Energy and its conversion to electricity What happens in the sun – our greatest source of Energy? How the sun's Energy reaches our planet – The electromagnetic spectrum Differences between infrared waves, visible light, and ultraviolet waves Exploring the relationship between wavelength and the Energy that the wave carries with it
Week #5	Introduction to photovoltaic cells – conversion of electromagnetic waves to electricity. Explanation of the basic parameters of solar panels: Open Circuit Voltage, Short Circuit Current, Maximum Power, Exploration of how a solar panel works and its relationship with the following parameters: Solar Panel area, Distance from the Light Source, and Angle of Incidence of the light
Week #6	Batteries: how they store electrical Energy Battery Parameters: Energy Density and State of Charge Different types of batteries (Lead and acid, Lithium) Advantages and disadvantages Charging a battery with a solar panel Project #1 – solar charger for cell phone
Week #7	Alternating current The war of DC vs. AC currents – Edison vs. Tesla. History of the development of the electrical grid from its beginnings in DC to its change to AC and currently the smart grid that combines the two resources. How to convert the Energy stored in a battery (DC) into alternating current that can be used with regular items around the house – How an inverter works
Week #8	Development of a microgrid based on a 12V battery, a solar panel, and a 12VDC to 110 VAC or 220 VAC inverter. Preparation of a presentation that explains how the microgrid works and how its capacity could be increased to provide electrical energy to a room, a house, etc.

3.1.5 Logistics requirements for the educational model

Based on blended education, this educational model requires a minimal set of conditions to facilitate its successful implementation. The following is a list and description of such requirements. Most of these conditions fall within the scope of the Local Institution. Also, the Remote Instructor must have the minimum CIT requirements to provide a high-quality learning experience via remote learning and the time to conduct the synchronous activity aligned with the local Institution.

The local Institution needs to have defined:

a) The group of students that will participate in the project (day and time for synchronous activities)
b) In which subject of the existing curriculum will the project be introduced, since students will receive a grade for their participation in the course, within the Institution's evaluation system (The course must not be perceived as an EXTRA activity or additional load neither for the students nor for the local instructor)
c) Have a committed teacher (one of the designated subjects) who collaborates in synchronous activities and follows up on the project and asynchronous tasks. This teacher needs to have a minimum of CIT capabilities and skills to collaborate effectively in the project (e.g., managing the video conferences and the access to the students to the LMS platform)
d) Have defined the classroom where the synchronous activities will take place. This classroom must have the following facilities:
    - Internet connection
    - The computer for the videoconference is connected to a projector so students can see the class.
    - The camera focused on students.
    - A speaker system that allows students to hear the explanations.
    - A wireless microphone connected to the video conference (so that the teacher and students can communicate with the remote instructor
e) Materials for the implementation of micro-grid examples. The idea is that students not only use simulations but build two examples with easily accessible materials:

- Example #1 is a cell phone charger using solar Energy. This project would be individual and use disposable materials, and the students would take their work home as the product of their effort.
- Example #2 is a micro-grid that can illuminate a room or house not connected to the electrical grid. Ideally, groups of students will build this project, but due to cost, they will build a demonstration unit.

f) Students must have access to an email account to access the LMS Canvas platform.
g) Students will have to access the platform BEFORE the project begins.
h) Ensure students have access to computers with internet connection during the week to implement asynchronous activities.

4. Evaluation of the students and the project

The evaluation of the students for participation in the course is totally under the purview of the local teacher. Although the implementation of the course through the platform Canvas provided information regarding the participation of the students in the activities of the course, such as a final exam of the content, reading quizzes, assignments, final presentations, etc., the decision on how to use them to grade their students is up to the local instructor.

Regarding the project, the evaluation has the objective to answer two research questions:

1) What is the gain in learning the physical concepts of solar energy and conversion to electricity in high school students in a rural community, remotely implementing the teaching-learning process through STEM-oriented project-based Learning (PBL)?

2) What is the change in attitudes towards STEM careers of high school students in a rural community who remotely implement the teaching-learning process through STEM-oriented Project-Based Learning (PBL)?

4.1 Design of the Content Exam

To answer the first question, the project designed an exam of 20 multiple-choice questions following the topics covered in the Didactic Sequence. To validate the exam, the project followed the Validation Process (Coral, 2009) [16]. After developing the first draft, the exam was presented to two external experts from two different countries in Latin America (Uruguay and Mexico) to check the face validity of the exam. Although the researcher speaks Spanish fluently, it was necessary to ensure that the vocabulary used in the exam was understandable by the local population that would participate in the course. Then, the exam was shared with six external experts from three different countries in Latin America (Argentina, Colombia, and Mexico), with the Scope and Sequence of the course. The external experts assessed the relevance of the items proposed and returned a Google form with their assessment regarding their relevance on a 5-point Likert-type scale from **Totally Disagreed** to **Totally Agreed**. Only the items where all the experts Agreed or Totally agreed were included in the final version of the exam. Then, the exam was tested on an audience similar to the one that would participate in the project to test the internal consistency of the exam. Using the software SPSS, we calculated the Cronbach Alpha, which was 0.71. When testing regarding the changes in Cronbach Alpha when eliminating certain items, only five items show that Alpha can increase, but only to a maximum of .741; therefore, eliminating certain items does not have a significant change in the calculated index. According to Taber (2017) [17], the Alpha coefficient of the exam can be identified as relatively high (0.70 – 0.77).

After the validity and reliability process, the content exam measures what it was designed to measure: the student's knowledge of the content presented during the course.

4.2 Student Attitudes Toward STEM (S-STEM) Survey

The *Student Attitudes Toward STEM (S-STEM)* Survey was used to answer the project's second research question. This survey was developed at the Friday Institute for Educational Innovation – College of Education North Carolina University [18] to collect and interpret information about students' attitudes toward science, technology, engineering, and mathematics subjects, postsecondary pathways, and career interests. This instrument is free to access and modify for educational use and can be adapted to local conditions as long as the source is cited.

Given that the audience of the course is Spanish-speaking, the project used, translated, and adapted a version of the S-STEM survey in Spanish. The translation and validation of the new instrument were performed by Bautista-Diaz et al. (2020) [19]. The final instrument contained 32 items on the Likert scale. The 32 items that make up the attitude survey are classified as follows:

- Items 1 to 5 interest and disposition towards mathematics.
- Items 5 to 9 interest and disposition towards science.
- Items 10 to 15 interest and disposition towards technology and engineering.
- Items 17 to 19 – 21 and 22 professional expectations in science.
- Item 20 professional expectations in mathematics.
- Items 23 to 26 professional expectations in engineering and technology.
- Items 27 to 32 personal appreciations (27 and 30 in science, 28 and 31 in mathematics, 29 and 32 in engineering and technology).

4.3 Other Instruments

Given that the primary goal of the project is to develop an educational model for remote blended education that can be replicable using other contents and different remote instructors, it is necessary to gauge how students and local instructors interact with the material of the course, the delivery of the synchronous and asynchronous session, and the impressions of the strengths and weaknesses of the course from the perspective of the local instructor. These instruments are:

- The student survey was conducted to collect information on students' impressions of synchronous and asynchronous activities. Students were asked to complete it each week after completing their asynchronous activities.
- Exit survey for students. Students were asked to complete it at the end of the project to gauge the overall feeling of the participants regarding their whole experience in the project. This survey included open questions to allow students to comment on what works, what does not, and what we can do to improve the course.
- Exit survey for local teachers. Local teachers were asked to complete it at the end of the project.

Exit Interview: Local instructors were interviewed about their impressions and critical points in the project to propose changes and confirm what worked well and what needed improvements.

5. Implementation of the Pilot plan – Project MicroGrid V 1.0

Using the resources developed to facilitate the Implementation of the educational model for remote blended learning, the organization of the logistics arrangements that led to the successful Implementation of the course began in August 2023. The following table details the implementation steps.

Table 2. Description of the timetable for the Implementation of the pilot project

Dates	Description
August – September (2023)	Administrative meetings to arrange the logistics needs of the project – Pilot Plan Project MicroGrid V 1.0
September-November (2023)	Implementation in the local institutions of the course MicroGrid V 1.0
December (2023)	Analysis of the data from the project MicroGrid V 1.0 (quantitative and qualitative) Definition of suggestions to improve the model
January – February (2024)	Implementation of the improvements discussed with the local instructors. Administrative meetings to arrange the logistics needs of the project – Project MicroGrid V 2.0
March-May (2024)	Implementation in the local institutions of the course MicroGrid V 2.0
June (2024)	Analysis of the data from the project MicroGrid V 2.0 (quantitative and qualitative)

5.1 Administrative meetings to arrange the logistics needs of the project – Pilot Plan Project MicroGrid V 1.0

During August-September 2023, the researcher met with the representatives of four Local Institutions to prepare and ensure that the local institutions' logistics requirements will be met and that the local instructors are being assigned and are ready to participate in the project. In addition to two Zoom meetings of all the members involved in the project (July 27 and September 7), the researcher generated a WhatsApp group to facilitate communication between all the parties involved in the project. (Note for the reader: In Latin America, the use of WhatsApp as a primary communication tool is well accepted).

From this process, FOUR educational local institutions (the institutions participating remotely on the project) completed all the requirements to run the course. The following is the demographic data of the participants who completed the information survey of the project.

Table 3. Demographics of the Local Institutions Students

Students per Local Institution

Name of the Local Institution	Number of Students
I.E. Adolfo Gom	22
Jerarquicos --	16
Sgto Cabral - S	6
UASLP -- Mexico	65
Total	114

Age

		Number of Students
Valid	14 years old	5
	15 years old	8
	16 years old	28
	17 years old	37
	18 years old	15
	More than 18 y.o.	18
	Less than 13 y.o.	3
	Total	114

Gender

		Number of Students
Valid	Female	43
	Male	70
	Prefer not to say	1
	Total	114

Institution #1: Escuela de Educación Técnica Profesional y Secundaria Orientada N° 662 Juan Bautista Cabral – Pcia. de Sta. Fe - Argentina

Institution #2: Centro Educativo Jerárquicos – Pcia. de Sta. Fe - Argentina

Institution #3: Institución Educativa Rural Departamental Adolfo León Gómez - Pasca - Cundinamarca - Colombia

Institution #4: Coordinación Académica Región Huasteca Sur, Universidad Autónoma de San Luis Potosí - Tamazunchale – San Luis de Potosí – México

Each institution received a slot time and the corresponding link for the synchronous meeting, published on the Canvas LMS. The videoconferences were implemented via the platform Zoom.

Institution #1: Mondays from 10:30 to 11:50 Local Time

Institution #2: Mondays from 13:15 to 15:00 Local Time

Institution #1: Tuesdays from 7:00 to 8:50 Local Time

Institution #1: Fridays from 16:00 to 18:00 Local Time

5.2 Implementation in the Local Institutions of the course MicroGrid V 1.0

The course occurred at the four sites participating in the project from September 11th through November 17th. Here is the summary of the number of synchronous meetings per site

Institution #1: Juan Bautista Cabral School (Arg) – Seven 90-minute sessions

Institution #2: Centro Educativo Jerarquicos (Arg) – Seven 105-minute sessions

Institution #3: I.E Gómez –Colombia – Eight 105-minutes sessions

Institution #4: UASLP – Mexico – Eight 120-minute sessions

Note: All synchronous meetings are recorded and posted on Canvas. Local teachers led the asynchronous meetings on their own time.

The activities followed the Didactic Sequence presented above. Before starting the Implementation of the program, the local instructor was responsible for the following actions: 1) ensure that all the students have an email account, 2) ensure that all students have access to the Canvas LMS platform, 3) ensure that despite the limitations all students completed the content knowledge pretest and the attitude survey. The pre-test and the survey were administered via Google form to ensure anonymity. The students submit only a personal code to facilitate the match between pre and posttest and survey.

Even though a great effort was invested in the preparations for the implementation of the project, some unexpected problems arose, such as:

- Each site had previously undeclared holidays, which extended the time of the pilot plan (at all four sites)
- In one place, weather conditions (abundant rain) caused the synchronous session to be canceled and rescheduled (twice) – on days of heavy rain, students do not have access to the school.
- Problems with Internet connectivity canceled a session.
- The "designated classroom for the synchronous class" was shared with other site functions, leading to multiple conflicts during the synchronous session.

After the seven (or eight) project sessions, all the sites concluded implementing the didactic sequence. At this point, students prepare and present a final project, demonstrating what they learned during the course. Most participants also completed the posttest and post-attitude and requested exit surveys.

6. Evaluation of the Pilot Plan - Project MicroGrid V 1.0

6.1 Content Knowledge - Initial comparison between the groups

Given that the participants' institutions have very diverse backgrounds, it was interesting to determine if the group's participation was significantly different. Using the pre-test results and applying the ANOVA analysis, it can be observed that the three groups have a very similar mean that is not significantly different p=0.04. Only the Sargento Cabral group has a significantly different mean. This analysis includes ALL the valid pre-tests taken before the start of the project - n=97

Table 3. Descriptive statistics and ANOVA test results of the pre-test

Descriptives

Pre Test

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Sargento Cabral	6	5.5000	2.58844	1.05672	2.7836	8.2164	3.00	10.00
Jerarquicos	15	10.0000	3.94606	1.01887	7.8147	12.1853	4.00	20.00
I.E. Gomez	17	7.3529	2.52342	.61202	6.0555	8.6504	4.00	13.00
UASLP	59	8.3220	3.68801	.48014	7.3609	9.2831	3.00	19.00
Total	97	8.2371	3.60490	.36602	7.5106	8.9637	3.00	20.00

ANOVA

Pre Test

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	105.283	3	35.094	2.857	.041
Within Groups	1142.264	93	12.282		
Total	1247.546	96			

A one-way ANOVA was performed to compare four different sites on exam scores.

A one-way ANOVA revealed that there was not a statistically significant difference in mean exam score between the groups (F(3, 93) = [2.857], p = 0.041).

It is possible to see that, except for the group Sargento Cabral, which has only six valid pre–tests, the groups are not significantly different. This means all the groups are at the same initial level regarding the content.

6.2 Content Knowledge - Final comparison between the groups

The four participating groups took the content knowledge posttest. Implementing the ANOVA test in this case, it is possible to see a significant difference between the groups p=0.011. The Jerarquicos site group has a lower mean than the rest of the groups in the project. n=99

Table 4. Descriptive statistics and ANOVA test results of the posttest

Descriptives

Post Test

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Sargento Cabral	14	13.0000	4.59096	1.22699	10.3493	15.6507	7.00	20.00
Jerarquicos	15	10.6000	3.54159	.91443	8.6387	12.5613	6.00	17.00
I.E. Gomez	13	13.2308	5.03577	1.39667	10.1877	16.2739	6.00	20.00
UASLP	57	14.7895	4.31665	.57175	13.6441	15.9348	5.00	20.00
Total	99	13.6970	4.53884	.45617	12.7917	14.6022	5.00	20.00

ANOVA

Post Test

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	221.528	3	73.843	3.903	.011
Within Groups	1797.381	95	18.920		
Total	2018.909	98			

Note: anecdotic information from the Jerarquicos local instructor mentions that the participant group from this local institution also performed poorly in other subjects this academic year.

6.3 Content Knowledge - Comparison between the results of students who completed valid pre and posttests:

Not all pre- and posttests obtained were valid. Participants needed to complete the identification fields correctly, making a match between the pre-and posttest sometimes not possible.

The changes in the mean between the pre- and posttest were analyzed using a Paired T-test. The analysis was implemented for all students and complemented with a Paired T-test per site to assess the potential changes in content knowledge at each local institution. Many students submitted multiple tests since they completed the test via Google Forms. This study considered the student's first test (pre or post).

6.3.1 Paired T-Test of ALL the students from the project N=75

The results of the content knowledge test before the intervention were M1 = 8.21 (SD = 3.68), and after the intervention, they were M2 = 13.69 (SD = 4.466. The paired T-Test revealed a significant difference between the conditions, t (74) = 8.315 p < 0.001. Therefore, we reject the null hypothesis and conclude that the intervention significantly improved the participants' content knowledge.

Table 5. Results of the Paired T-Test for the paired pre and posttest

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre Test	8.21	75	3.681	.425
	Post test	13.69	75	4.466	.516

Paired Samples Test

		Paired Differences							Significance	
					95% Confidence Interval of the Difference					
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided p	Two-Sided p
Pair 1	Pre Test - Post test	-5.480	5.708	.659	-6.793	-4.167	-8.315	74	<.001	<.001

The following graph shows the relationship between the posttest and pre-test. Most of the participants who completed both showed a higher posttest score.

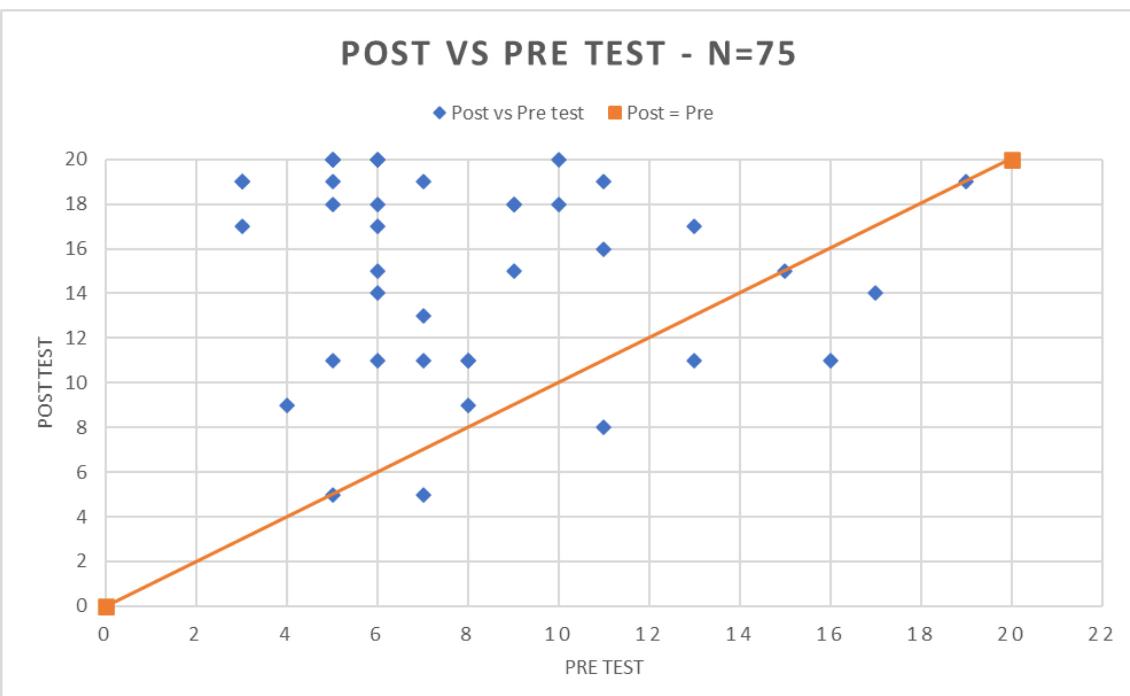

Figure 10. Graph showing the relation between pre and posttest of the participants

6.3.2 Paired T-Test by Local Institution

This section includes the Paired T-Test results of the valid pre and port tests by local institutions and a brief commentary regarding the results based on the exit interviews with the local instructors.

Institution #1 – Sargento Cabral

This site is a rural school in a small town. On this site, most students did not have personal email accounts. The local instructor needed to generate the email account for them and introduce them to how to use it. The lack of students' email accounts delayed the start of the use of the Canvas platform and, with it, the completion of the pre-test. Only six valid pre- and posttest pairs emerged from this site. Despite suspended classes (heavy rain), students completed the hands-on projects, and the mean of the posttest was very high, M=13.0 N=14. A Chicago-based Non-For-Profit Organization donated the equipment for the large-size microgrid.

The results of the content knowledge test before the intervention were $M1 = 5.50$ ($SD = 2.588$), and after the intervention, they were $M2 = 9.67$ ($SD = 2.733$). The paired T-test revealed a significant difference between the conditions, $t(5) = 2.57$, $p = 0.05$. Therefore, we reject the null hypothesis and conclude that the intervention significantly improved the participants' content knowledge.

Institution #2: Jerarquicos:

This site was selected to be a control site, a private urban institution with access to all the resources needed for the project, and where the students also have access to a computer with internet at their homes. Despite the intentions of the local instructor, the participating students did not engage or demonstrate an interest in the project and its content. From the interview with the local instructor, "students did not take the work seriously, did not participate actively in the synchronous meetings nor complete the assignments." The school mainly purchased materials for the hands-on activities. A Chicago-based Non-For-Profit Organization donated the equipment for the large-size microgrid.

The results of the content knowledge test before the intervention were $M1 = 8.91$ ($SD = 3.081$), and after the intervention, they were $M2 = 11.09$ ($SD = 3.208$). The paired T-test revealed that there was NOT a significant difference between the conditions, $t(10) = 1.67$, $p = 0.108$. Therefore, we accept the null hypothesis and conclude that the intervention did not significantly improve the participants' content knowledge.

Institution #3: I.E. Gomez

The I.E. Gomez is a regional rural school where students from close small towns and farms attend. On this site, the Local Instructor organized the parents and the students to find resources for purchasing the materials needed for the hands-on activities. This site confronted several problems of connectivity, where the local instructor used her private phone as a hotspot, paying from her pocket for the service. Note: In Latin America, most personal internet connections and usage are through cellular phones and NOT via an internet-dedicated connection. Moreover, they pay for data plans as they use them. It is rare to have a plan of unlimited data! (Caplan, 2021) [15]. This site represents the typical local institution with basic educational needs of resources the model intended to provide.

The results of the content knowledge test before the intervention were $M1 = 7.18$ ($SD = 2.926$), and after the intervention, they were $M2 = 12.45$ ($SD = 4.987$). The paired T-test revealed a significant difference between the conditions, t (10) = 2.890, p =0.016. Therefore, we reject the null hypothesis and conclude that the intervention significantly improved the participants' content knowledge.

Institution #4 - UASLP

This site is a regional extension of the Universidad Autonoma de San Luis de Potosi (UASLP) and includes three different groups of students: Students from the local high school, students from the Engineering career first year, and a group of students from another university. On this site, the synchronous meeting occurred on Fridays in the late afternoon when the local high school students could travel to the campus. They have several schedule conflicts in using the videoconference room and connectivity. The site was run by five local instructors – three university professors supporting the students for the asynchronous work.

The results of the content knowledge test before the intervention were M1 = 8.64 (SD = 3.953), and after the intervention, they were M2 = 15.11 (SD = 4.182. The paired T-Test revealed a significant difference between the conditions, t (46) = 7.468 p <0.001. Therefore, we reject the null hypothesis and conclude that the intervention significantly improved the participants' content knowledge.

6.4 Student Attitudes Toward STEM (S-STEM) Survey

The 26-item Likert scale type was analyzed from the 62 participants who completed the pre and post-survey. A first comparison between the pre and post-mean per item shows that the mean of the post-survey item is higher than that of the pre-survey item, showing that the intervention did not negatively impact the perceptions of STEM and STEM careers on the students participating.

Then, when using the ANOVA test to see if there is a significant difference between the results of the survey PRE and POST intervention, no significant difference was found in any of the items, which indicates that the intervention has not had a significant impact on the students' attitudes regarding careers and topics in STEM.

6.5 Students exit survey analysis.

At the end of the pilot, students completed an exit survey. Many of the exit survey items were adapted from the *best practices and sample questions for course evaluation surveys* from the University of Wisconsin-Madison.

The students' exit survey includes the following items: 7 Items about the Remote Instructor, 7 Items about the Local Instructor, 6 Items about the academic materials and load covered during the project, and 19 Items about Student Self-assessment. All items were presented on a 5-point Likert scale where 1 represents Strongly Disagree and 5 represents Strongly Agree. All the statements were positive.

The exit survey also included three open questions: 1) What parts of the course helped you learn the most? 2) What parts of the course were obstacles to your learning? and 3) What changes to the course could improve your learning?

N=79 of the participating students completed the exit survey. The following is a summary of the general results of the students' exit survey.

The scores for the seven statements regarding the Remote Instructor received a value between 4.14 and 4.27, indicating the students' general satisfaction with him.

The seven statements regarding the Local Instructor scored between 3.86 and 4.33, indicating the student's general satisfaction with him.

Regarding Academic materials and course load, the scores of the six statements received a value between 2.78 and 4.20, indicating the students' general satisfaction regarding the activities and load of the course. A critical point in this section is that students have a neutral view regarding implementing remote (virtual) laboratories. The researcher hypothesized that students would be more engaged in working with virtual situations and explorations.

Regarding the students (self-evaluation), there are some points to remark between them:

- Students declared that they were not well prepared for the synchronous sessions (3.49),
- Students have a neutral position regarding the difficulty of the asynchronous assignments (3.10),
- Students were engaged in the hands-on work (4.27)
- Students will recommend this type of course to other students (4.28)
- Students will take another course with this blended learning methodology (3.9)

The last question of the students' exit survey explicitly asked to value their impressions regarding their experience in the course, from 0 being the WORST to 10 the BEST. Below, there is a histogram with their answers.

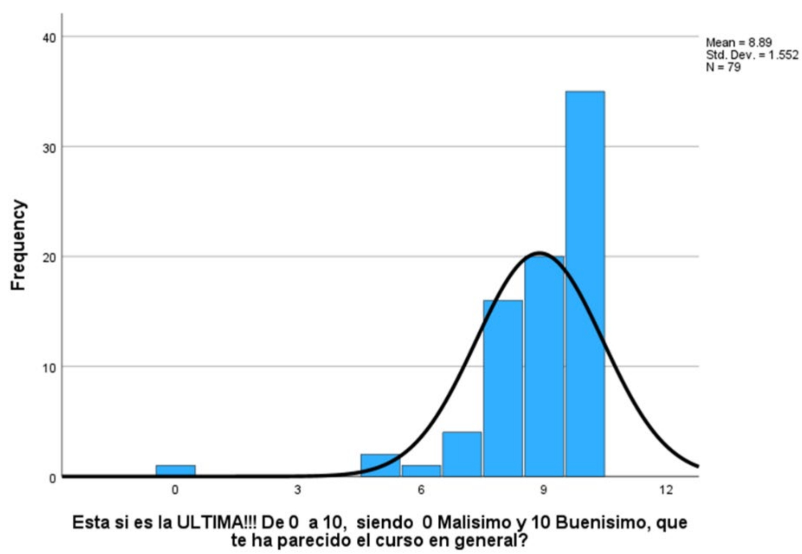

Figure 11. Graph showing the results to the question regarding their experience in the course from 0 being the WORST to 10 the BEST

The graph shows that many participants (those who completed the exit survey) had a good experience during the project implementation.

Following is the summary of the qualitative analysis of the responses to the three open questions:

1) <u>*What parts of the course helped you learn the most?*</u> When analyzing the answers to this question, it is possible to identify the emerging constructs can be identified (74 student voices)
   - Emphasis on Practical Activities (23 voices)
   - Practical Application of Knowledge (16 Voices)
   - Importance of the Teacher's Explanations (12 Voices):
   - Interaction with the Teacher and Virtual Classes (8 Voices):

The idea that stands out the most among all the phrases is the importance and effectiveness of the practical approach in the course. Students highlight the relevance of practical activities, such as the construction and application of solar panels, and interaction in virtual classes to understand theoretical concepts. They say that the combination of theory and practice, along with participation, is critical to the success of the course.

2) What parts of the course were obstacles to your learning? When analyzing the answers to this question, the following emerging constructs can be seen (71 student voices)

- Connectivity Problems (17 Voices)
- Challenges and Obstacles of Virtuality (15 Voices)
- Difficulties with Specific Content (9 Voices)
- Personal Factors (6 Voices)

Student statements about obstacles to learning during the course reflect an uneven adaptation to virtual teaching. Challenges are associated with connectivity and understanding specific topics such as mathematics and circuit laws.

3) What changes to the course could improve your learning? When analyzing the answers to this question, the following emerging constructs can be seen (71 student voices)

- Suggestions to Improve interaction (43 voices)
- Request for More Practices and Activities (37 Voices)
- Recommendations to Improve Communication (20 Voices)

Below is a list of ideas from analyzing the students’ responses.

- **Need for More Practice**: More practical activities to improve understanding and application of the concepts taught on the course.
- **Improve interaction:** more communication with the teacher, classes where doubts can be raised, and constant feedback.
- **Adaptation of the methodology:** Explain and implement concepts simultaneously, reduce meeting time, and be more interactive.
- **Greater flexibility:** changes in schedule, fewer but more laborious tasks
- **Improved connectivity**.
- **A more practical and less theoretical approach:** The preference for a more practical and less theoretical approach to teaching stands out.
- **Patience and clarity in explanations:** the importance of instructors being patient when explaining and providing detailed and clear explanations.

- **Commitment and active participation:** Students emphasized the importance of their commitment and active participation in classes and activities.

6.6 Exit interview with the Local Instructors

Following a designed interview protocol, the researcher has two interview sessions with the local instructors. The interviews (via videoconference Zoom) were recorded with the local instructors' permission, and the audio was transcribed for further analysis. Each local instructor expressed his/her experience during the pilot project. The discussion elicited suggestions for modifications of the present course (Canvas platform, Synchronous meetings, the actions to take BEFORE the start of the course, and the general structure of the course. The following is a summary of the points the local instructors suggested could improve the course and make it more successful on the subsequent trial.

6.6.1 Regarding the Canvas Platform

- Put tests and quizzes on Canvas to facilitate peer assessment and minimize logistics problems.
- Develop a Week #0 module where the local instructors work with the Canvas platform and digital resources with the students.
- Develop intermediate projects for students to learn/practice making simple presentations in asynchronous meetings.

6.6.2 Regarding synchronous classes

- Develop a lesson plan to ensure the interaction and inclusion of the local instructor with the remote instructor when implementing the synchronous classes " together. "
- We will have a synchronous meeting led by the remote-local instructor's TEAM and an asynchronous meeting led by the local teacher.
- Add physical materials for students (lamps. Batteries, meters, etc.) to facilitate the physical exploration and experiments of the concepts learned in the synchronous meetings and review them via simulations. – Students demonstrated that they preferred hands-on experiments over virtual experiments.
- Develop a training course for local instructors regarding the use of several applications, the Canvas LMS platform, and the content knowledge of the course(probably develop a MOOC-type structure)

6.6.3 Regarding the actions to take BEFORE the start of the course

- Develop and implement training sessions for local instructors on applications and content before the Implementation of the course
- Ensure local instructors understand their role and actively participate in synchronous and asynchronous meetings.

6.6.4 Regarding the structure of the course

- Add to the course, in addition to the two-period synchronous class, an asynchronous period class led by the local teacher (in the pilot project, this independent work timeframe was not required; it was only suggested).

- Add at least one EXTRA synchronous meeting so that participants from different countries can work/collaborate on a project and have international cooperative work experience.

7. Conclusions of the Pilot – Project MicroGrid V1.0

The idea behind this presented work is to develop an educational model that facilitates the development of high-quality STEM courses in rural, remote schools. The paper identifies the main concerns for implementing the model: the deficit of instructors in place with the credentials to provide the designed learning process and the lack of CIT management capabilities in those areas to provide a virtual learning environment up to the learning community's needs.

With these considerations in mind, the author developed a blended learning environment based on synchronous meetings via videoconference and vast media resources to assist effective communication between the remote instructor and the local instructor. These meetings were complemented by asynchronous independent work, presented through Canvas LMS and led by the local instructor.

A pilot project was implemented in four local institutions in eight to ten weeks. The analysis of the data collected during the project – content knowledge test and attitude and exit surveys showed that the project significantly impacted the participants. From the students' perspective, they declared (via the test and the exit surveys) that they learned and enjoyed being part of this initiative. From the local instructors' perspective, they continue participating in evaluation and debriefing meetings for their comments and experiences to be included in the future developments of the project – the Implementation of the Project MicroGrid V 2.0

The pilot project results demonstrate that it is possible and feasible to generate, with minimal resources, a high-quality learning environment for students in rural or remote places. This effort requires 1) the decision and desire of the remote expert (a qualified educational professional like you, the reader) to invest time in the development of a remote course and the time to implement it via blended learning and 2) a learning community, mentioned in the paper as Local Institutions ready to contribute with the logistics and materials needs of the course, and being flexible enough to allow the project to be part of the learning local curriculum.

The capability is vast. There are plenty of excellent instructors in urban areas with the expertise needed to develop and implement this blended methodology. These instructors can develop courses with different content needed in rural and remote areas. Technology is also available in urban areas and, therefore, can also be available in remote locations.

It is our responsibility to promote the conditions. Hence, these kinds of projects that propose to bridge the non-privileged rural learning communities with the privileged urban communities become the norm and not the isolated idea of an individual. We are in the age of Diversity, Equity, and Inclusion (DEI). It is time that each one of us take the leadership role and move a step forward towards learning equity (not equality) for our students in rural and remote areas. Please contact the author if you want to extend your reach to non-privileged rural communities.

Following is the timetable for the continuation of the project via the Implementation of the Project MicroGrid V 2.0

Next steps toward the Implementation of a new trial of the educational model – Project MicroGrid V 2.0

Here is the timetable for the Implementation of the subsequent trial of the project Microgrid V 2.0

2) Course update on the Canvas platform (December '23 - February '24)
3) Development of the preparatory course for local teachers (February '24)
4) Contact with the institutions that will run the project (December '23 - February '24)
5) Project implementation (March-May 2024)
6) Project evaluation (June 2024)
7) Presentation of a second article on the Implementation of the project after the modifications (June – December 2024)

8. Acknowledges

The researcher would like to extend his gratitude to the following individuals who participated in the project as Local Instructors: Dra Carmen del Pilar Suarez Rodriquez, Dr. Raul Castillo, Dra Patricia, Prof Angel Patricia Cifuentes Guerro, Prof Sergio Baudin, and Prof Marcos Scharfspitz. Without your total commitment and participation, the pilot project could not have had the excellent results it produced.

Also, the researcher would like to thank the Local Institutions that collaborated and made possible the Implementation of the Pilot project: Universidad Autonoma de San Luis de Potosi Huasteca Norte, Centro Jerarquicos, Escuela Sargento Cabral, and the Instituto Educativo Gomez. These institutions provided the leadership and logistics needed to make this international project a reality.

Finally, the researcher would like to thank the Chicago-based Organization Urban Technologies Laboratory for providing the materials to two Local Institutions, and the Instituto Politecnico Nacional for supporting the development of this project.

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