Promoting quality STEM Education in the time of Social Distancing (Other)

Abstract

The pandemic produced by COVID-19 has forced a radical change in the strategies and methodologies used to share and transmit knowledge. With the closure of the Schools / Universities, the educational process has been radically transformed from one day to the next.

STEM education is based on collaborative work, inquiry, experimentation, problem-solving, and project generation. This type of education encounters many obstacles in the present situation: students do not have access to laboratories, materials, and other essential supplies to implement an educational process of quality.

The Institution has developed alternative ways to promote quality STEM education for our students when learning from their homes with the present limitations. These activities allow students to explore phenomena through "remote" labs (not simulations), project generation using a supply of pre-existing materials (constraints that any project has at any time), and in particular, the development of projects based in easy to find at home materials.

In this paper, the Author will present three strategies to promote STEM education through remote learning: 1) Laboratory activities for college-level students 2) Hands-on activities for high-school students through informal education settings, and 3) Activities for the public at large through social media (Facebook liv and YouTube) and sponsored by public institutions. The Author implemented these strategies successfully in a university setting, in Out of School Time (OST) programs in the City of Chicago for non-privileged student groups, and with multiple public institutions partners in different countries.

Introduction

The world passes through the second year of a global coronavirus COVID-19 pandemic when writing this manuscript. This pandemic has had a devastating effect in all ambits of society, from the economic fall that leads to high unemployment, lockdowns, and the need to impose social distance, health, and other rubrics of our lives [1].[2]

This situation leads to radical changes in society's activities, particularly education. Closing the educational institutions from k-12 to universities imposed by the pandemic generated the need to change the way education is implemented at all levels. The education process needed to continue. Therefore this new situation required a change from the well-known in-person learning model to an also known but neither well developed and not well-implemented distance learning [3].

This change from in-person to remote or distance learning also brought a new set of learning and teaching paradigms for the students and the teachers. From students' perspectives, they needed to have access to remote learning tools and master the use of these tools. Teachers also needed the same access to improve and develop new skills and educational material that can foster their students' education, accompany, guide, and motivate them in this new learning environment – remote learning [4]. Teachers' competencies need to rise to the need above the knowledge of the subject matters but develop flexibility and mastery of remote learning, where digital interactivity has become the primary way to communicate with their students.[5]

This need for adaptation required a review about promoting the remote learning practices of laboratories and other types of hands-on activities. The process to adapt in-person laboratories to remote laboratories requires attention to the design of both the pedagogy and the technological/delivery infrastructure and how these elements interact. [6]. According to Gamage et al., 2020 [7], the majority of the laboratory classes are performed in the actual laboratory, not accessible at the time of the pandemic COVID-19. On the other hand, virtual labs, remote control labs, or video-based labs are good alternatives when students cannot perform the laboratory tasks in person. [8[. Remote laboratories allow the implementation of experiments through the internet, whereas video-based activities provide a step-by-step overview of a real lab. In this way, students can visualize the whole experimental process and its environment through a video. Zhai, Wang, and Liu provide examples for some of the above labs in electrical engineering [8].

In March 2020, Columbia College Chicago decided to close the campus following the lockdown policies and health concerns. Faculty received instructions to transform their courses from in-person to remote learning. One of the challenges was to facilitate remote science laboratories. Also, the close campuses cause the youth to migrate from in-person to remote learning for their informal learning activities. This manuscript will describe the design and implementation of remote science laboratories for a non-major science course (Part A) and remote learning STEM activities in an academic enrichment informal program for high school youth (Part B).

Part A - Science Remote Laboratories in Higher Education for non-science majors

As presented above, the Covid 19 pandemic disrupted the regular implementation of the teaching and learning activities, in all levels, from k-12 through higher education. One of the significant changes was the closing of the educational institutions and the change of students participation from presential to remote education. The college's directive of moving from in-person to remote learning generated the need to continue the learning process effectively.

Before describing how presential courses were adapted to become remote learning, it is vital to remark what were the assumptions used for the design of the remote learning courses:

1) The students have access to an internet connection
2) The students have access to a computer
3) The students can participate in a synchronous meeting

Some courses, particularly those that do not involve implementing hands-on activities or interaction between students, adapted their material from presential to remote learning mode in a very fluid way introducing asynchronous activities complemented with synchronous meetings. A different challenge was to generate a remote learning environment for courses that included laboratory activities.

Following is the description of the process to design and implement remote laboratories to provide non-science major students with the laboratory experience needed to fulfill their requirement – a science course with a laboratory component. These laboratory experiences are part of SCIE 140 – Science and Technology in the Arts. This course is an elective class that fulfills one of the Liberal Arts and Science (LAS) requirements to obtain the bachelor in arts (BA) from Columbia College Chicago, a science course with a laboratory component (designation SL). Below are presented the LAS Core objectives and Learning outcomes that the course and the laboratories need to achieve.

Liberal Arts and Sciences Core Objectives: This course partially fulfills the 6 Science credits required by the Liberal Arts and Sciences Core Curriculum and satisfies the science with lab requirement. Students will be able to:

- *Conduct research and, as part of that process, learn to measure, evaluate, and assess.*
- *Understand and apply the scientific method of inquiry.*
- *Utilize various tools of analysis to enable critical thinking.*

General Science with Lab Learning Outcomes: Upon successful completion of science with lab courses, students will be able to:

- *Formulate and test hypotheses, identify and evaluate evidence, draw appropriate conclusions, and identify limitations and sources of uncertainty.*
- *Discover, evaluate, and assess the credibility of general interest publications related to the scientific subjects they study.*
- *Formulate and investigate testable scientific questions through the practice of observation.*

As general background, the students that take this class are non-science majors. Their majors are from the arts and communication fields (cinema, television, theatre, journalism, art management, and others). This course has no pre-requisites and did not serve as a pre-requisite for other courses in the students' possible majors. By students declarations, many students stated that they took this course because 1) fulfill the LAS requirement that they need to take "out of the way" and 2) looks interesting. The course and laboratory experiences are not at the center of students' attention and interest.

The Author designed and implemented the laboratory experiences prior to the pandemic with the students. Given the characteristics of the students, it was necessary to develop the laboratory experience surrounding a question that is of interest to them and not a simple experiment to do. To make this point clear, measuring the velocity of the sound in the air as a task is not relevant to the students. Finding which sound produced on the stage will arrive faster to the audience (bass middle or treble) generates a discussion that leads to the need to figure out a way to find an answer. Following the discussion, students develop their research question, identify the variables

(Independent, Dependent, and Parameters of the experiment), define their hypothesis, and define what they need to do to test their hypothesis. After students complete these definitions, the instructor introduces the devices (experimental equipment) students will use to test their hypothesis and discuss the procedure.

Introduction to the Remote Laboratory Experience

The same strategy was used the develop the remote laboratory experience. In synchronous discussion, and after the introduction to the topic at hand, the instructor presents the open and general question (e.g., What sounds will the audience hear first at a concert, the bass or the treble?), then through an Instructor lead discussion, students in groups will establish:

- The research question (e.g., Is there a relationship between the frequency and the velocity of the sound in air?)
- The variables of this experiment (e.g., the frequency is the independent variable, the velocity of the sound in air is the dependent variable, and the temperature in the room is one of the parameters of the experiment)
- What is their group hypothesis (e.g., the velocity of the sound in the air does not depend on the frequency)

Then in the same synchronous meeting, the instructor introduces the experimental apparatus that students will use in the laboratory and explains how the apparatus works and the safety measures involved in implementing the experiment. Then the instructor asks the students to define the procedure and the data collection process to collect relevant data to test the proposed hypothesis based on the apparatus presented. Until this point, the instructor reproduced the same procedure the instructor will use in a presential classroom, but via video conference.

Implementation of the remote laboratory experiment

For the implementation of each experiment, the instructor produced a video. The instructor filmed a video for each laboratory. The video shows how to assemble the experiment apparatus and use it in the same way it would occur in the face-to-face class. Following the procedure presented in the instructor lead discussion, the video shows the information collection process without adding any comments – only the information of the instruments – the operator activates the independent variable and collects the information of the dependent variable(s). in the spirit to make the process INTERACTIVE, the video is, in reality, a Video Quiz. The Video Quiz includes questions during the implementation of the experiment to ensure students' knowledge and understanding of what they are doing.

Given that the implementation of the experiment is remote, all the questions are multiple-choice questions. Any time a question is presented, the video stops, and the students need to answer. If the answer provided is the correct answer, the video continues. If the answer is wrong, the students need to rewind the video, observe the phenomenon again, and answer the question. It is important to remark that the questions presented in the video quiz are the same questions the instructor will ask the students during the implementation of the experiment in face-to-face learning. These questions are conceptual and critical thinking questions regarding the experiment, such as identifying patterns in the collected data, if the specific point in the data collected is an outlier and another similar type of questions. At the end of the video, the student will have a complete set of data, similar to the one the student will obtain if he/she were implementing the experiment in the laboratory. The video quizzes are a function available in the application **Studio**, one of the video applications interacting with Canvas LMS. Then. The system records the video quiz score in the Canvas LMS grade book.

In the case of implementing the remote experiments for the course SCIE 140 – Science and Technology in the Arts, the videos were filmed in the laboratory using multiple cameras. The cameras focused on specific sections of the experimental apparatus to facilitate students reading the instruments as they were supposed to when implementing the experiment in presential mode.

As an example, in Figure 1, it is possible to see three parts of the experiment: on the left part, the whole apparatus and the reading of the frequency from the wave generator, on the right part of the apparatus that allows students to measure the length of the air column, and in the right upper corner, the display of the intensity of the sound meter. In this experiment, the operator decides the length of the air column (e.g., 25 cm) and modifies the wave generator's frequency until obtaining the first maximum of the intensity of the sound. This louder sound will indicate the resonance frequency. From there, it is possible to calculate the $speed\ of\ sound = \lambda * f = 4 * L * f\ resonance$, where L is the length of the air column.

Figure 1 – Opening of the video quiz for Experiment #2

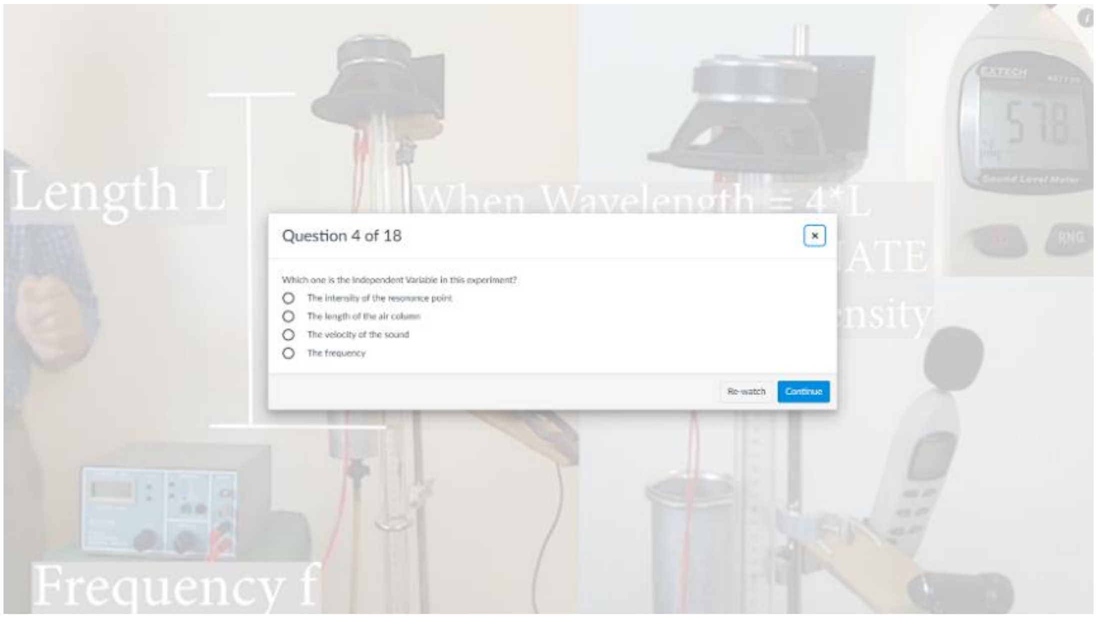

Figure 2 – Example of a question of the video quiz

The final score of the video quiz, which shows the student's understanding of the implementation of the experiment, is a part (e.g., 50 %) of the final grade of the laboratory. The other 50% is the production of the laboratory report.

Preparation of the Laboratory Report

Each experiment is presented as an assignment in Canvas LMS, as shown in the picture below.

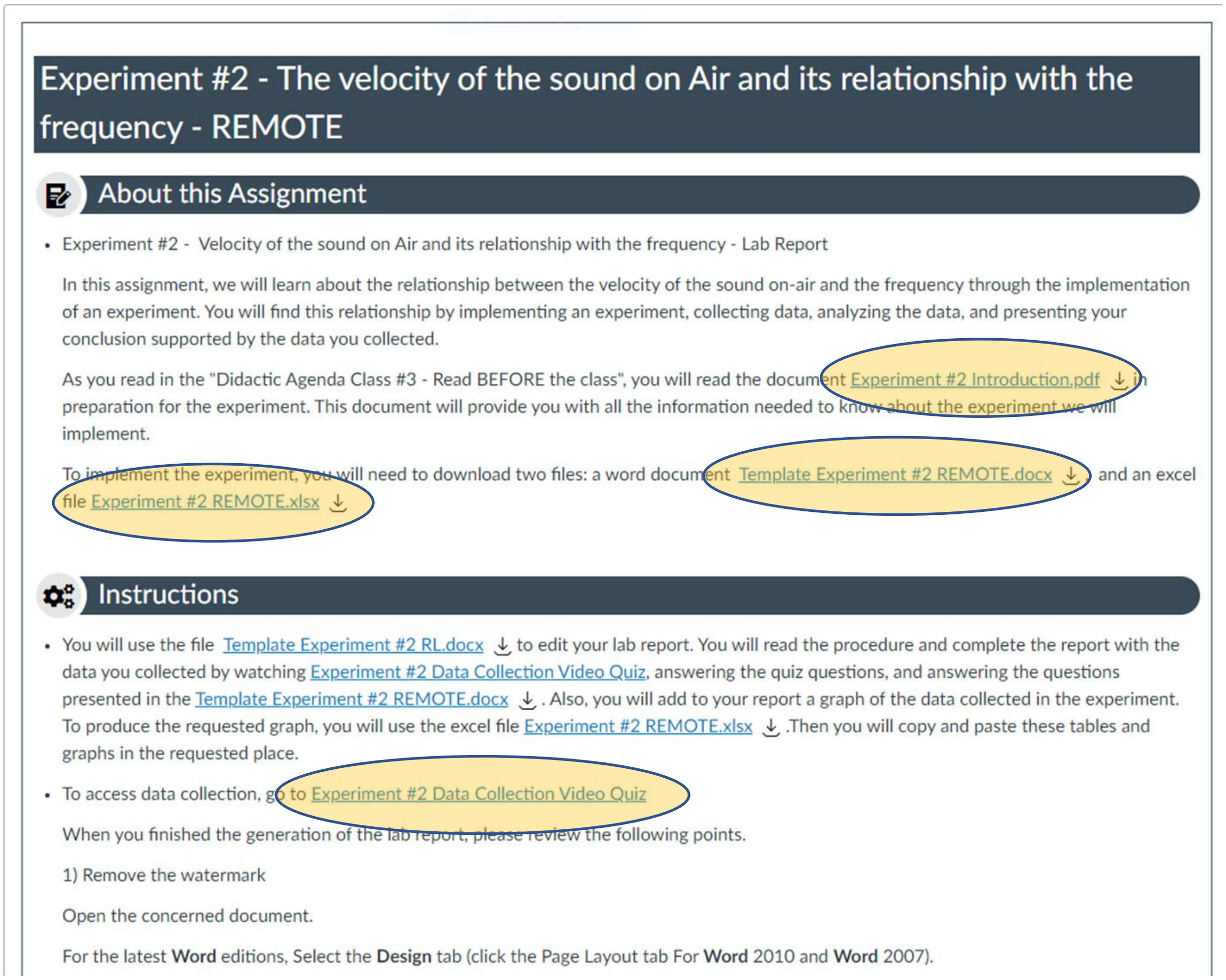

Figure 3 – Example of the presentation of the Remote Laboratory as an assessment in Canvas LMS

Each experiment includes the following files (see ellipses on the assignment page above) :

- Introduction to the experiment: a PDF file that includes a summary of the instructor lead discussion
- Template of the Experiment: word file of the experiment for the student to complete after the experiment implementation
- Excel file of the experiment: designed to produce the graphs required to analyze the data collected. Then students copy and paste the graphs in the laboratory report template.
- Video Quiz access: This link facilitate access to the video quiz relevant for this experiment.

Once the students have collected the information through the video quiz, a section in the laboratory report template explains the data analysis. The data analysis includes two sections: Data analysis and Final Statement. Students describe the relationship between the independent and dependent variables in the Data Analysis section. Using the data collected and the previous description, students produce a final statement explaining the relation between the independent and dependent variables based on the data collected. Then, based on students' hypothesis and final statement, students will produce their conclusion, stating that the data collected supports or rejects their proposed hypothesis in this setting. The process ends when students submit their laboratory report as a PDF file. The laboratory report is the same laboratory report that students would produce if they participated in the in-person laboratory experiment.

What is the difference between the remote laboratory proposed and a simulation?

There are multiple definitions of the remote laboratory, and one that best fit the model described and implemented in the manuscript is:

“Remote Laboratory: An expression used to describe the reconfiguration of laboratory assessment based on simulated experimental environment convergent with "learning by doing" paradigm. The data collected in the pandemic contains and reinforces various experiences connected with remote real laboratories: an innovative tool, software, networks or telecommunications, lab reports (in and on virtual space), remote experimentation, qualitative metrics (indirect interviews and surveys), web remote laboratory, remote architecture, part of VISIR (Virtual Instrument Systems in Reality), online workbenches, and others.” [9].

On the other hand, one definition of a scientific simulation is:

” Scientific Simulation: It is a technique of imitating the behavior of an actual or theoretical system by means of an analogous mathematical model. In the simplest sense, a system is a set of interacting identities. The mathematical equations that produce the model represent the various processes within the target system. Currently, the simulation uses cover a wide range of applications within the areas of research, analysis studies, system design, training and education, entertainment, and so forth.” [10]

In the presented model, the remote laboratory is acting upon an experimental environment, a video with the implementation of the experiment in a real experimental setting. On the other hand, a simulation is not an experimental environment. A simulation implements a mathematical model developed upon previous knowledge obtained from exploring the physical phenomenon. Although students can directly manipulate the independent variable and the experiment's parameters in the simulation, the results emerging from the simulation are the product of the mathematical model, a simplified representation of the phenomenon at hand.

Differently, in the remote laboratory model, although the independent variable is not manipulated directly by the students, the results obtained are the physical responses of a physical system measured with the appropriated instruments. This fact introduced in the data collected from the remote laboratory other factors that the simulation does not include, such as measurements errors, materials error, and more, and the experience of collecting information from an actual device.

From the research of Lima et al., 2017, [11] students expressed their understanding of simulation and a remote laboratory. Students stated that the simulation represents something that is not taking place. Regarding the remote laboratory, students stated that although they are working on a computer, the phenomenon is/was physically done in a laboratory somewhere.

Assessment of the remote laboratories experiments

After implementing the course, students completed an anonymous survey to share their impressions of the remote laboratories (n=148). Students participated in three different groups regarding the type of laboratory. Part of the students only worked with remote laboratories (n=50), part of the students worked in a mix using in-person and remote laboratories (n=57), and the last group only participated in in-person laboratories (n=41).

Note that the name Online Laboratory was used when producing the survey. The type Online Laboratory is what this manuscript refers to as Remote Laboratory to avoid misunderstandings.

Figure 4 – Distribution of the students participating in the laboratories by type of laboratory n=148

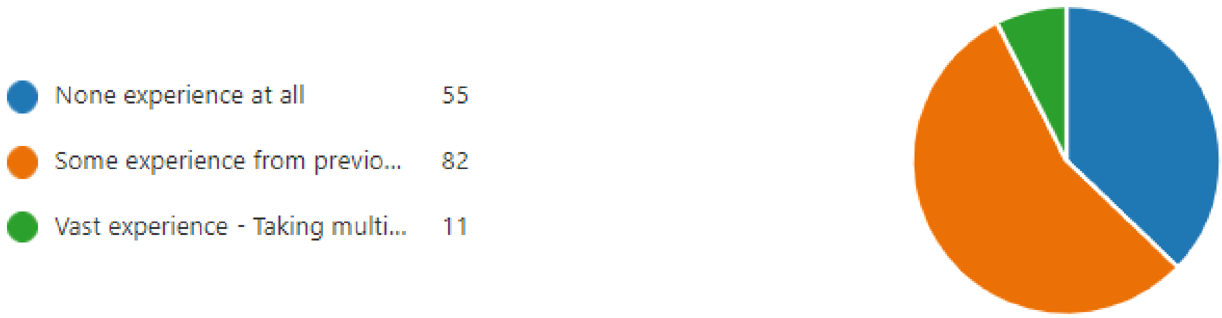

Figure 5 – Distribution of the students participating in the laboratories by previous experience n=148

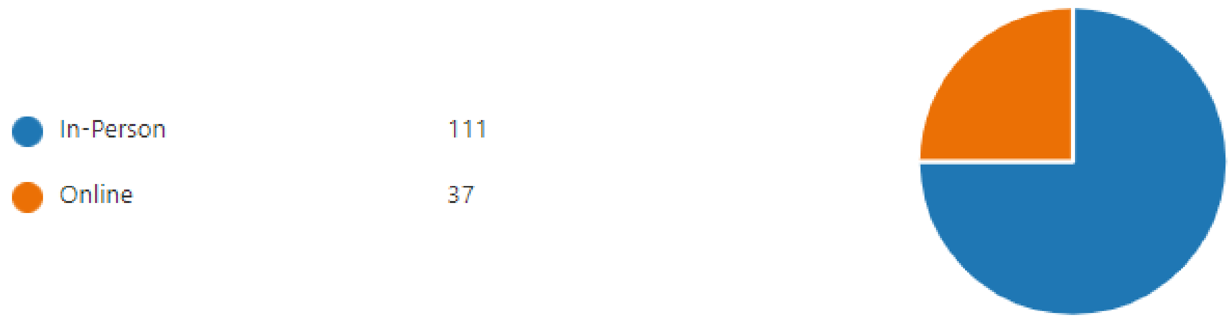

Figure 6 – Students' distribution participating in the laboratories by learning preference n=148

The following Table 1 lists statements students answer in a Likert scale mode, where five represents Strongly Agree, and one represents Strongly Disagree. Presented in Table 1 is the percentage of students that Strongly Agree and Agree with the statements, per type of laboratory.

Table 1 – Comparison of the agreement with statements from students (n=148) that participate in three different types of laboratory experiences.

Statement	All n=148	Remote n=50	In-Person n=41	Mix n=57
The material in the introduction to the Lab file explained clearly the content of the lab	75 %	82 %	73.1 %	66.7%
I recommend that others read the introduction to the Lab file BEFORE doing the experiment.	78.4 %	86 %	73.1 %	75.4 %
The templates helped me to understand the task ahead better	87.7 %	92 %	92.7 %	80.7 %
The templates make the process to write the lab report very easy	83.7 %	88 %	82.9 %	80.7 %
The introduction of the video quizzes explained clearly the experiment setup and procedure	NA	90 %	NA	75.4 %
The questions presented in the video quizzes contributed to understanding the content of the experiment better	NA	86 %	NA	75.4 %
You can easily collect the data for the experiment from the video quiz	NA	86 %	NA	78.9 %
The video quiz is an excellent approximation to an experiment implemented in an In-Person setting	NA	80%	NA	63.2 %

In response to the question: To what extent do you feel that the labs reinforced the information, you received in the classroom lecture? (1- minimum to 5- maximum) here is the distribution for the type of laboratory

Table 2 – Students appreciation of the contribution of the laboratory by type

Students appreciation	1	2	3	4	5	Average
Type of Laboratory						
Remote n=50	2	1	9	17	21	4.08
In-person n=41	1	1	9	21	9	3.88
Mix n=57	1	3	16	25	12	3.77

Following are representative excerpts of open students' statements produced when answering the following questions by type of laboratory.

To the question: If you **DID NOT** enjoy the laboratories learning experience, please describe the single most important reason why you felt so.

Remote laboratory	In-Person Laboratory	Mix of In-person and Remote Laboratories
Sometimes the research questions ended up confusing me more because a lot of times, the information I got was more advanced than what we were learning. *You made us use Microsoft spreadsheet which is a horrific thing to do to your students. If you use spreadsheet you're telling your students you hate them.* *Because of how much work and time the labs took, it became stressful and hard to stay focused at times.*	*I felt this way because it felt like busywork.* *They were repetitive and boring. However, that's how most labs are, so I don't see fault in the labs, but instead think it's just a conflict of interest from me.* *in immense amount of unimportant homework compared to other classes.*	*I liked the in-person labs bc those were easier to follow, online was more difficult and I was already unmotivated about science.* *Sometimes the instructions weren't super clear, making moving forward from different steps a challenge* *I'm just not really good with math and science and thus have no enjoyment in doing it. It was more of a challenge for me then anything and not really a fun challenge.*

To the question: If you **DID** enjoy the laboratories learning experience, please describe the single most important reason why you felt so.

Remote laboratory	In-Person Laboratory	Mix of In-person and Remote Laboratories
The labs were enjoyable because they allowed me to learn the material, but they gave me guidance as I went so I felt confident in my ability to succeed. *When going over notes, it was hard to remember what I had learned during the class period for homework, but the laboratories helped me remember and comprehend the material.* *I specifically enjoyed the labs in which we were able to record and document our own results. I felt that this hands-on experience while at home really assisted with the learning experience and helped to engage students further.* *I felt that they provided the common rationale and applications of what we were learning in a more clear way. I was able to connect how I may use this information to my personal life more effectively as the labs are essentially real life examples.*	*It allowed me a way to actually do something with the material that we were being taught during the lectures. I was able to actually see (or hear) the effect of the changes that we were making instead of just having an understanding about them.* *I enjoyed the laboratories because it allowed me to actually see and experience what we were learning about in class, with hands on real world tools, and situations. It also made it easier when trying to solve an equation to have the ability to recall a certain lab we did, and apply a real situation to a solvable equation.* *It was an easy way to see an example of what we just talked about in class play out in front of us.*	*I enjoyed the lab learning experience because having hands on control of the content we were learning helps retain what you learn much easier.* *Overall, they were easy to follow and did a good job of truly helping us understand the material, especially when they were in-person* *The videos that you make, especially for data collection, are very thorough. They were engaging and informational.*

Analysis of the assessment of the remote laboratories

Before starting the discussion regarding the assessment of the remote laboratories, it is important to remark that the survey intended to gauge the impact of the remote laboratories. After reviewing the data collected, it is clear that many of the students who took the survey can not separate their impressions regarding the laboratories and the fact that they took a class that is a requirement and, in general, they have a shallow interest in the subject. This fact came to light when answering the question "If you did not enjoy the laboratory experience…". 59 students from n=148 (39.9%) answered this question. The majority of the responses were related to constructs such as "I do not like science," "It is too much work," and "It is not part of my major."

Given that part of the non-science major audience (59 of 148 students) had a negative perspective of the course independent of the laboratories, it will be interesting to see the impact of the remote laboratories in these two groups: the groups with a negative and positive perspective of the course. To gauge the impact of the remote laboratory, we will use the answer of two questions:

1) What was your level of enjoyment as you went through the Science and Technology in the Arts labs experience during this semester and

2) To what extent do you feel that the labs reinforced the information you received in the classroom lecture?

The Table includes a summary of the answers to the two questions per group.

Table 3. Students enjoy the laboratories and feel the usefulness of the laboratories by type and group.

Statement	All types	Remote	In-Person	Mix
I enjoyed the laboratories learning experience and felt it helped me learn the material	n=100	n=34	n=30	n=36
To what extent do you feel that the labs reinforced the information you received in the classroom lecture?	4.19	4.32	4.1	4,14
I did not enjoy the laboratories learning experience but did feel that it helped me learn the material	n=34	n=12	n=9	n=13
To what extent do you feel that the labs reinforced the information you received in the classroom lecture?	3.65	4.17	3.11	3.54
I did not enjoy the laboratories learning experience and did not feel that it helped me learn the material	n=14	n=4	n=2	n=8
To what extent do you feel that the labs reinforced the information you received in the classroom lecture?	2.5	1.75	4	2.5

From the data presented above, it is clear that although 59 students explicitly declared that they did not enjoy the laboratory experience (and as presented above, some of these reasons are not related to the laboratories), only 48 chose the possibility I did not enjoy the laboratories.

However, 34 (71%) also declared that the laboratories helped them learn the material from this group.

Another interesting point to remark is that the students' feelings that the laboratories learning experience reinforces the information learned in the lectures. The highest score, 4.32 of 5, belongs to the group of students who enjoyed the laboratory experience using the remote laboratories and the score of 4.17 of 5, for those who did not enjoy the remote laboratory experience but believe that helped them learn the material.

Also, it is essential to remark that 37% declared they do not have laboratory experience, and 55% of the students declared they have some experience from previous science courses in high school. Only 8% declared they have vast experience in participating in scientific laboratories.

Table 4 summarizes the students' enjoyment of the laboratory experience and the declared previous laboratory experience and type of the laboratory.

Table 4. Students enjoyment by the declared previous experience and laboratory type

Statement	Previous Laboratory experience	All types	Remote	In-Person	Mix
I enjoyed the laboratories learning experience and felt it helped me learn the material	None Some Vast	n=33 n=59 n=8	n=15 n=19 n=0	n=7 n=19 n=4	n=11 n=21 n=4
I did not enjoy the laboratories learning experience but did feel that it helped me learn the material	None Some Vast	n=15 n=18 n=1	n=4 n=8 n=0	n=4 n=5 n=0	n=7 n=5 n=1
I did not enjoy the laboratories learning experience and did not feel that it helped me learn the material	None Some Vast	n=7 n=5 n=2	n=3 n=1 n=0	n=1 n=0 n=1	n=3 n=4 n=1

Table 5 presents the average value of the answer to the question: To what extent do you feel that the labs reinforced the information you received in the classroom lecture? (1- minimum to 5- maximum), by the students' declared previous laboratory experience.

Table 5. Students' feeling of reinforcing learning by making the laboratories based on their previous laboratory experience.

	All the laboratory types	In-Person	Remote	The laboratory reinforces the learning All types	The laboratory reinforces the learning In-Person only	The laboratory reinforces the learning Remote laboratory
Non-Laboratory Experience	n=55	n=12	n=43	3.71	3.58	3.75
Some Experience	n=82	n=23	n=59	4.01	3.95	4.03
Vast Experience	n=11	n=5	n=6	4.09	4.2	4

From the data presented above, it is possible to see that for students who do not have a robust previous experience implementing scientific laboratories, the remote laboratories presented a possible alternative experience. This remote experience promoted their learning of the course's content in some way more than for those that only implemented in-person laboratories.

Table 6 presents the students' impressions regarding the video quizzes by the students' declared previous laboratory experience. Students answer a list of statements in a Likert scale mode, where five represents Strongly Agree, and one represents Strongly Disagree. The Table presents the percentage of students that Strongly Agree and Agree with the statements, per declared laboratory experience. The Table only includes the students that used the video quizzes.

Table 6. Statements regarding the video quizzes remote laboratories and the students' declared previous laboratory experience (None, Some, and Vast)

Statement	All n=107	None n=43	Some n=58	Vast n=6
The introduction of the video quizzes explained clearly the experiment setup and procedure	82.2%	74.4%	89.6%	83.3%
The questions presented in the video quizzes contributed to understanding the content of the experiment better	80.3%	72.1%	89.6%	50%
You can easily collect the data for the experiment from the video quiz	82.2%	76.7%	87.9%	66.7%
The video quiz is an excellent approximation to an experiment implemented in an In-Person setting	71%	72.1%	75.9%	33.3%

From the data presented in Table 6, it is possible to see that for those students who have some experience making laboratory experiments, more than 75% agree that the video quiz presents a valid alternative to implement an experiment. The same group of students who have some experience implementing laboratory experiments and did the experiment via remote laboratories (n=58) expressed that their feelings about the labs reinforcing the information learned in the classroom lecture ranged 4.04 of a maximum of 5. These results indicate that for this group, the remote laboratories served as a feasible alternative for in-person laboratories.

The sample of the students that declared they have vast experience implementing science laboratories and implemented remote laboratories is very small (n=6). It is clear that for this group, after having real experience working and learning in a real laboratory, the video experience was not selected as an excellent alternative for a laboratory experience.

Conclusion

The pandemic Covid 19 caused the closing of the educational institutions and forced their faculty to move from the established in-person to remote instruction. One of the significant challenges was moving activities that required hands-on interaction with materials and equipment that are only accessible in specific frameworks, such as a laboratory. To overcome this challenge, the instructor developed a methodology of using video quizzes with a set of complementary documents. These video quizzes and documents provide a learning environment similar to the one the students are exposed to when participating in an in-person laboratory.

When implemented the remote science laboratories in the art and communication institution with the specific audience of non-science major, the results collected through the survey from the 107 students who participated in remote laboratories was encouraging:

1) 65% (70 of 107) declared that they enjoyed the remote laboratories, and 23.4% (25 of 107) declared that they did not enjoy the laboratories but helped them learn the material.
2) When answering the question: To what extent do you feel that the labs reinforced the information you received in the classroom lecture? The scoring average of the students participating in remote laboratories was the largest: 4.32 of 5 for those who enjoyed the laboratories. For the students who did not enjoy the laboratory but felt that the laboratories helped learn the material, the score was also high, 4.17 of 5.
3) The students with previous experience implementing science laboratories declared the higher agreement 75.9%, n=58 with the statement: The video quiz is an excellent approximation to an experiment implemented in an In-Person setting. This point shows that students with a previous background in implementing scientific laboratories saw the remote laboratory as a valid option to implement laboratory activities.
4) On the other hand, students that declared having vast experience implementing science laboratories expressed that the remote laboratories are not an excellent replacement for the in-person laboratory.

As the data collected showed, the implementation of remote laboratories using video quizzes can be used as an alternative for the in-person laboratories when the circumstances impose the need for social distance. These remote laboratories never were designed to replace the in-person experience. It will be the interest of the Author to develop and implement similar laboratories but designed for a student's population for which the course and the remote laboratory will be part of the degree requirement.

Part B - Implementation of a STEM Academic Enrichment program for high-school students through informal education settings via remote learning.

The pandemic Covid 19 and the need to minimize the possibilities of spreading the disease also affect informal education settings. In the City of Chicago, multiple agencies needed to suspend the programming they were implementing in the in-person mode and move to remote learning. These organizations, which mission is to promote non-privileged youth, find themselves in a situation in which:

- The youth participating in the programs can not meet physically. At the difference of the higher education students, a vast majority lacks the resources needed and the skills to support an effective remote learning strategy.
- The instructors in these programs, in general, are professionals in their fields but not educators. The instructors lack the knowledge, experience, and tools to manage a reliable remote learning process.
- The organizations and the instructions, at their core, were not designed to provide remote learning strategies. One of the main goals of these organizations is to "provide a nurturing environment for the youth," in other words, provide a safe place for the teens to learn and grow in their neighborhoods.

In past years, the Author developed two STEM academic enrichment programs for After School Matters (ASM): The Junior Research Scientists and Come Youth Ambassadors [12] and was one of the primary instructors of the programs. In the current Covid 19 situation, ASM requested the development of a remote learning alternative to the program Comed Youth Ambassador to continue the implementation of the program. The program ComEd Youth Ambassadors is sponsored and supported by the Local Electrical Company. Several instructors will implement this remote learning program in parallel in the summertime for six weeks.

The development of the remote learning program followed these assumptions

1) The teens' participants, as well as the instructors, will have access to a computer/tablet with a reliable connection to the internet
2) The teens participants will receive previous to the start of the course a material box that includes all the tools and materials needed for the implementation of the course
3) The course will be implemented for six weeks, meeting three days a week for four hours
4) Each meeting will include synchronous sections for the instructor to present and discuss topics with the participants and asynchronous sections for individual and group work
5) The several activities implemented during the course need to lead to the completion of a final project

To develop the remote learning strategy for all After School Matters programs, the institution choose to use the Google Suite as the remote learning axis for all the Institution remote programs. All the programs will use Google Classroom as the Learning Managing System (LMS), Google Meet as the video conference tool, and Google tools (google docs, slides, and sheets) as the main applications to produce and submit work.

Development of the remote learning program using the Google classroom LMS

The course Come Youth Ambassador aims to communicate the principles of how the electric grid works and the new features the Smart Grid have that improve the generation and distribution of electrical energy. The course was developed in 2013 and has run every summer since. The course was developed in previous in-person format and implemented in a format of 140 contact hours (4 hours a day, five days a week, seven weeks)

Moving the course from in-person to remote learning caused a change in the structure of the course, moving from 140 contact hours to a different schedule of synchronous meetings time, office hours' time, asynchronous and independent time. The Institution established that this kind of course (defined as an advanced apprenticeship) would be in this format: 54 contact hours: three hours a day, three days a week, for six weeks. From these 54 hours, 35 hours are active communication between instructor and teens – through Google meet, 19 hours of asynchronous work in a meeting day, and 24 hours of independent work outside of the frame of the meetings.

Given that many of the participants (teens and instructors) had no previous experience in remote learning, the base for the design of the LMS is the definition of one page, called Didactic Agenda. The participant can find all the material needed for the current meeting on this page. This page includes all the links the participants need to click to have access to the different activities of the session, such as videos, video quizzes, assignments, and others.

Below is an example of the Didactic Agenda

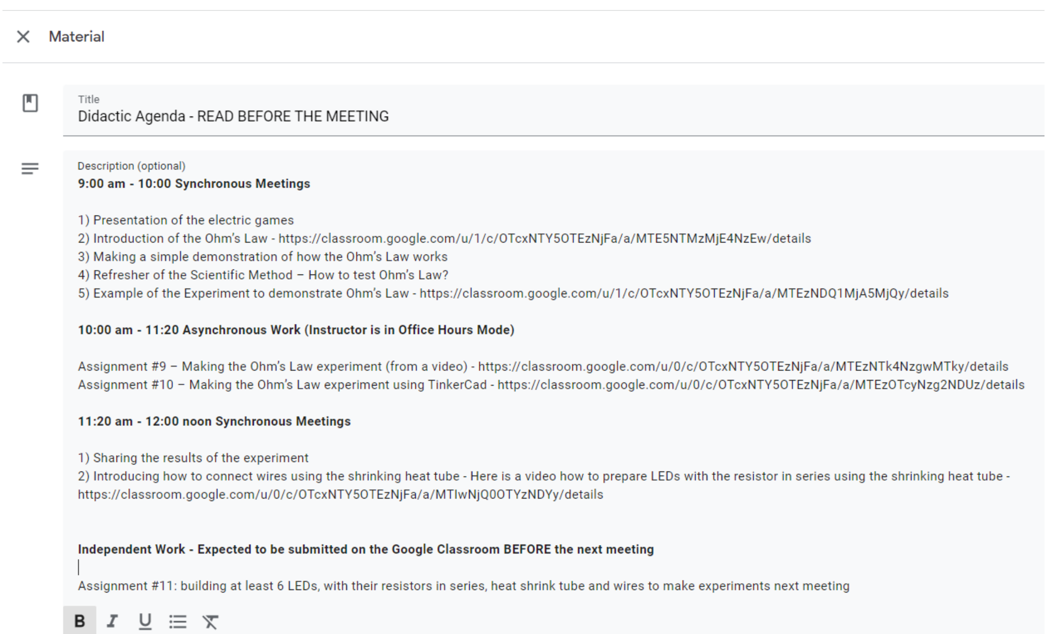

Figure 6. Google Classroom page showing the Didactic Agenda

Description of a generic daily session

The daily session is divided into two synchronous meetings, one asynchronous meeting, and then the participants embark on independent work preparing materials for the next session.

In the first synchronous meeting, 9:00 am to 10 am the instructor reviews questions from the previous session and introduces the topic of the current session.

In an asynchronous work from 10:00 am to 11:20 am, the participants are “dismissed” from the synchronous meeting and start to work independently, completing the assignments presented in the didactic agenda. At this time, the instructor reminds connected through the video conference, and the participants can access the instruction for questions regarding the work they are implementing. The instructor is in an “Office Hours” mode.

In a second synchronous meeting, from 11:20 am to 12:00 noon, the instructor discussed the work produced by the participants in the asynchronous time. Then, the instructor will introduce and discuss the topic and contents needed to know by the participants to explore and implement the assigned Independent work. Students will present the assigned work in the next session.

Implementation of experiments as well as hands-on projects in the remote setting

As explained above, the course Comed Youth Ambassadors curriculum is a STEM-based curriculum that requires scientific experiments to discover the phenomena and engineering designs projects to propose prototypes that can provide solutions to a given problem. This kind of curriculum requires the development and implementation of scientific laboratories and hands-on projects. In these laboratories and projects, the participants can discover scientific principles through their investigations, not by accepting what the instructor says as fact, and explore and try different ways to solve a problem designing their solution and building their prototype.

Scaffolders Videos to support the learning process

Given the situation in which: a) the teens and the instructor are in remote communication and b) the instructor is not an expert in the subject matter, the curriculum needed to provide the suitable scaffolders for the process to be successfully implemented. It is essential to have constantly present that the teens participating in this program are self-selected, and this course is not part of their school load. Furthermore, they receive a stipend for their participation in the course, not for their grade.

For these reasons, the curriculum includes three different kinds of videos: Laboratory video quizzes, Explanatory videos, and Design and Build videos. These videos' goal is to provide support for the instructors concerning the communication of the content and facilitate the participants to have access to the content knowledge and experiences that took place in the sessions in an asynchronous mode. The platform used for the design of the Video Quizzes and to store the other Explanatory or Design and Build videos is Edpuzzle. This platform is FREE and can generate video quizzes linked with the Google Classroom LMS's grade book and store videos and edit videos from other platforms such as YouTube.

Laboratory Video Quizzes: these videos were designed to facilitate the interaction between the participant and the learning material. The questions presented in the videos are designed to check and reinforce the topic that the participants are learning. For example, below is the link to a video quiz about “How to use a multimeter ." During the course, teens will often use the multimeter, and therefore this skill must be developed and assessed. The instructor has access to the video quiz results and can assess how to continue based on the results of the video quiz. The instructor can know if the teens viewed the video quiz, how many completed it, and their understanding of the topic by checking the participants' scores. Here is the link to a video quiz - https://edpuzzle.com/media/5ee531bdf7e1a03f050fa58d

Explanatory videos: these videos were designed to explain topics that sometimes the instructors have difficulty explaining, and these topics are essential to understand the course's main concepts. For example, below is an explanatory video regarding the impact of a long wire in the Transmission line of the Edison DC grid. One of the main concepts of this course is that the electric grid works with alternate currents, but at the beginning, the electric grid provided direct current. The videos explain why Alternate Current replaced Direct Current by showing the effects of a long wire in a simulation that the teens can see and understand. Here is the link to the Explanatory Video https://edpuzzle.com/media/5ef4ac8ada46273f0b531d56

Design and Building Videos: as part of the course, the participants need to design and build prototypes. The design and building process is different for each teen, following the skills and previous experiences each teen brings to the course. Therefore it was necessary to generate a path in which each teen will work at their own pace. To facilitate this process, the teens participated asynchronously using the Design and Building videos to generate their prototypes. These videos include the design and building process step by step using the tools and materials available to the teens. The teens received a box with tools and materials. The curriculum uses these videos as a construction guide for the participants. The teens can play, stop, rewind and play again, and in parallel, they can build the prototype. Here is a link to a Design and Building video that explains how to build an Ultra Violet light
https://edpuzzle.com/media/5ef3c6e8dd72193f2e61dec6

Development of the Tools and Material Box

According to Taher (2014) [13], the use of simulation alone is not very effective in promoting student learning. However, when using simulations in conjunction with a hands-on approach, i.e., hybrid or combinational instructional strategy, this approach shows to be more effective in the learning process and engaging students to be more involved in it. Many STEM learning experiences require experiments to learn about the scientific principles needed to solve a technological problem. Although many of these situations can be presented using existing simulations, this curriculum also introduces a set of several hands-on activities to promote and incentivize the participation of teens in the exploration, discovery, and problem-solving processes.

Given the remote nature of the course, it was necessary to develop a set of hands-on activities that obeys the following requirements:

1) The minimum amount of tools
2) The tools need to be easy to use, low cost, and safe to use
3) Complementary tools (or devices with similar functions) are available in a regular household
4) Disposable materials need to be easy to use, low cost, and safe to use

Under these premises, the program developed activities similar to those implemented in the in-person version of the program. These activities include: 1) Experiments (e.g., Exploring the relation between the light incident angle to a solar panel and the Short Circuit current - see video https://edpuzzle.com/media/5ef91f5b689b283f324e579c); 2) Building processes (e.g., Building and Electric Cart – see video https://edpuzzle.com/media/5efb8cd70461183f31446f6d) and 3) tips for their final design project (e.g., how to avoid that the battery will discharge through the solar panel during the night – see video https://edpuzzle.com/media/5efb971c6eae2f3f1caa54e4). Then the Institution produced the low-cost Tools and Materials Box. This developed box included all the tools and materials needed to implement the experiments, devices, and final project. For the final project, given that the final project is an Open project, the materials included in the box were enough to make an expected final project. Participants can use any available material to enrich their final project. A list of the Tool and Materials box content can is in Appendix #1.

Implementation of the program: Summer 2020 and Summer 2021.

The Organization" offers artistic and academic-oriented programs to the youth in "the city" during the academic year. The ComEd Youth Ambassadors program was offered to approximately 250 teens with 10 Instructors in the summer of 2020 and 2021. Each summer, the program was offered in five groups of 25 participants. Three of the instructors participated in both years, and one of them had two groups per year. It is important to remark that the Local Electrical Company that supports the program assessed the program developed and implemented in Summer 2020 and expressed their satisfaction with the program's outcome. The company requested to introduce in summer 2021 several activities related to Beneficial Electrification, and the instructors implemented these activities in summer 2021.

Before starting the program, the instructors participated in professional development (PD) session led by the designer of the remote course. Although the time of the PD was minimal, only three hours, the instructors developed an understanding of the principles of the remote program, its design, how to interact with the assignments, and some experience in leading activities through the video conferences (Google meet). One crucial concept transmitted during the PD is that the program developed and the LMS generated is ONLY a blueprint for the instructors to modify it according to the need of their teens participating in the different groups. The designer of the program did not participate directly in the instruction of the remote learning activities but served as a resource for the instructors to update their classrooms and resolve technical questions that emerged during the implementation of the program.

Although the program includes several levels of assignments, given the nature of the summer program, there was no enforcement on the part of the instructors to compel the teens to complete and submit the assignments. Therefore, the quantitative data collected of the assignments are very scarce and can not provide a reliable picture of the participants' work during the length of the program.

To be able to understand the way the program worked during the two summers, the Author invited some instructors to participate in a forum to discuss how they implemented the program, and in their opinion, what learning strategies used worked and which did not. From the instructors invited to the forum, only one replied. Fortunately, the instructor that participated in the discussion is the one that taught two groups each year. Following is the summary of the discussion with the instructor. All the comments presented below are anecdotic based on the impression of the instructor. The instructor is a public school Science Teacher with more than ten years of experience teaching in "the city" public school.

The instructor established that she taught two groups in summer 2020 and two in summer 2021. Each year she had one group from a neighborhood school from a non-privileged community (Group A) and a group from a community center that belongs to the organization in a more affluent neighborhood (Group B). This explanation is relevant because the students enrolled in each group are selected from the poll that participated in the different communities. Then, the instructor mentioned the different attitudes of the two groups regarding participation in the program. In Group A, participants did the minimum to continue enrolled in the program to receive the participation stipend. The instructor declared that engaging them in the activities was challenging, particularly asynchronous and Independent work activities. Also declared that some participants interested in working tried to build the projects, but the project and course level were “above their heads ." Regarding Group B, even though they were interested in receiving their participation stipend, their interaction with the material and the assignments were more effective, participating in the synchronous conversations and implementing the projects in the asynchronous session and independent work time. The instructor stated that between 50% and 75% of the teens participating in Group B completed the hands-on activities and projects.

When asked if the students had technical difficulties accessing and participating in the remote learning experience, the instructor stated that some participants had connectivity problems that limited their interaction. Another technical point presented was that the participants had not a regular place to work. Moving their material and tools from place to place renders some items to get lost, causing the participant not to finish the project or experience and increasing their frustration, which impacts their future participation.

When asked what did not work in her groups, the instructor declared that the program and activities were well designed. In her opinion, the activities were at a level that was above the preparation of the participants. The investigations through the implementation of an experiment were challenging, so she decided not to run them. She suggested the next year to simplify the research activities.

When asked what did work in her groups, the answer was straightforward: building projects. The students were engaged and eager to show their work in the next session. Also, the instructor declared that the Design and Building videos were the key to success. Students watched the videos and manipulated the materials and tools to accomplish the task at hand.

When asked what could improve the remote learning experience, she declared that the course was designed for high school students committed to learning and participating. The reality is that the population participating in the summer programs varies. One suggestion was to generate a course with more Hands-On activities to foster more teen participation and include a set of more investigative activities and projects to give the instructor the flexibility to supply activities that will be of interest to the different populations.

Conclusion

Running STEM academic enrichment programs in informal settings is a challenge, and it is more difficult to run this type of program in non-privileged communities.[14] Adding to the existing challenges, providing the course through remote learning strategies only exacerbates the difficulties. Even though it is not ideal, remote learning is a feasible way to continue reaching youth despite the social distance restrictions.

From the perspective of a summer program, it is possible to express that the program achieves its goal to provide opportunities to non-privileged communities with equity to high-quality STEM learning. Also, the participant teens had the opportunity to interact with material designed to enhance their learning capabilities and be exposed to a college learning experience.

Many readers wonder if this methodology, informal academic enrichment through remote learning, is effective and if the youth participating in this effort improve their content knowledge on the learned topic and have a significant gain in some areas. The material discussed above did not answer these questions, only describing a feasible way to reach youth when other “more conventional and tested paths” are not available.

It is noticeable that the development of the informal remote learning strategy was motivated by a necessity and not by design. To complement the findings of this manuscript, if in the following summer 2022 the organization will rerun the same program through the remote learning strategy, the Author will implement a designed assessment strategy to gauge the program's effectiveness and methodology.

Other ways to promote STEM learning in a time of social distance

The situation presented by the pandemic Covid 19 forcing the closing of the educational institutions and placing the audiences of the educational process in lockdown(students and teachers as one) generated the need to be creative and look for different ways to reach these audiences.

In addition to the two methodologies presented in this manuscript, the Author developed and collaborated to develop and test different strategies to promote STEM education among students and teachers. Bearing in mind that all communications with audiences can be only remote, these open the possibilities to work with whoever has access to the communication anywhere, opening the possibilities to expand the reach of the programs and initiatives beyond the physical place. All these initiatives have something in common:

1) synchronous communication (or quasi-synchronous via live streaming and chat dialogs) and the development of facilities where the instructor can show and explain concepts and present experiments and building processes similarly as the instructor will do in case of teaching in the in-person mode.

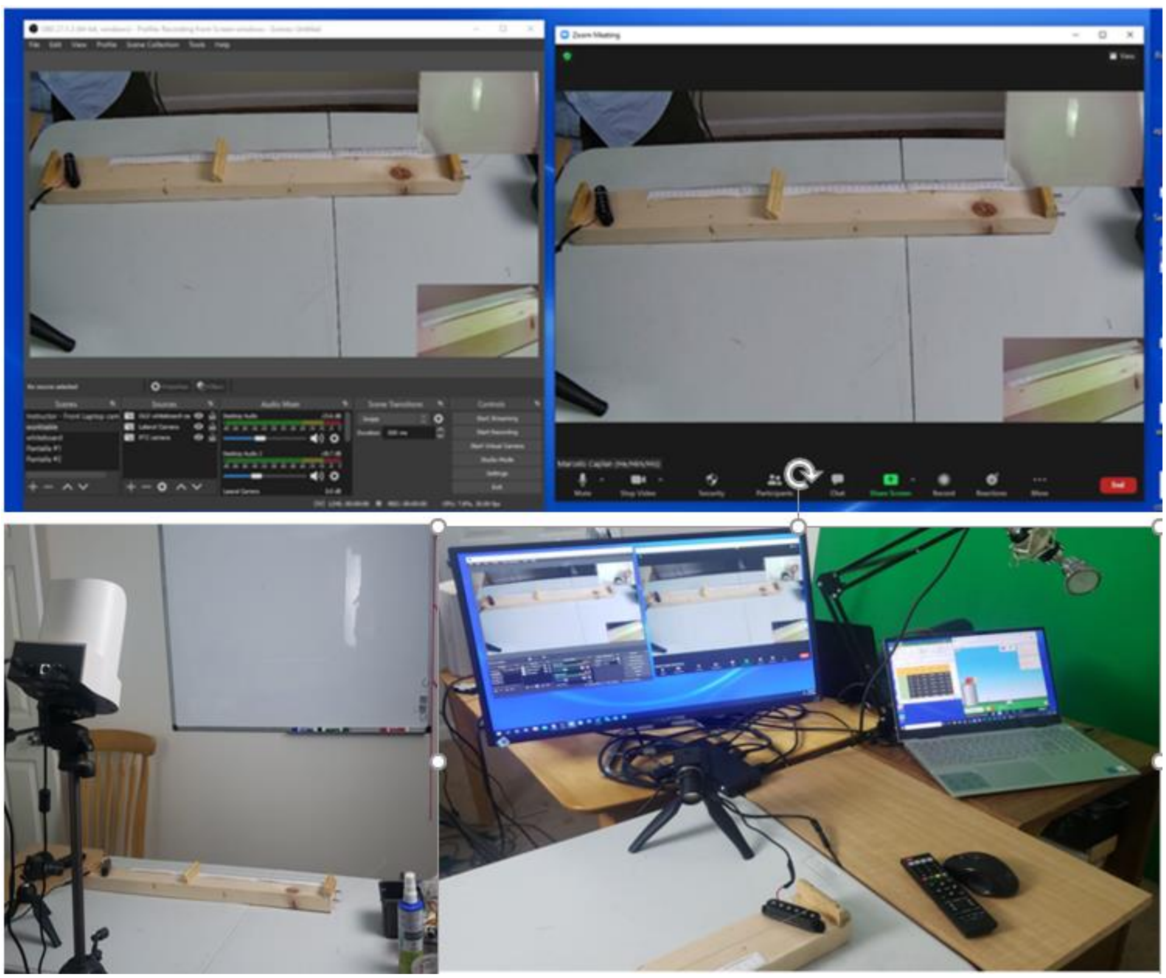

Figure 7. The setting of the transmission classroom

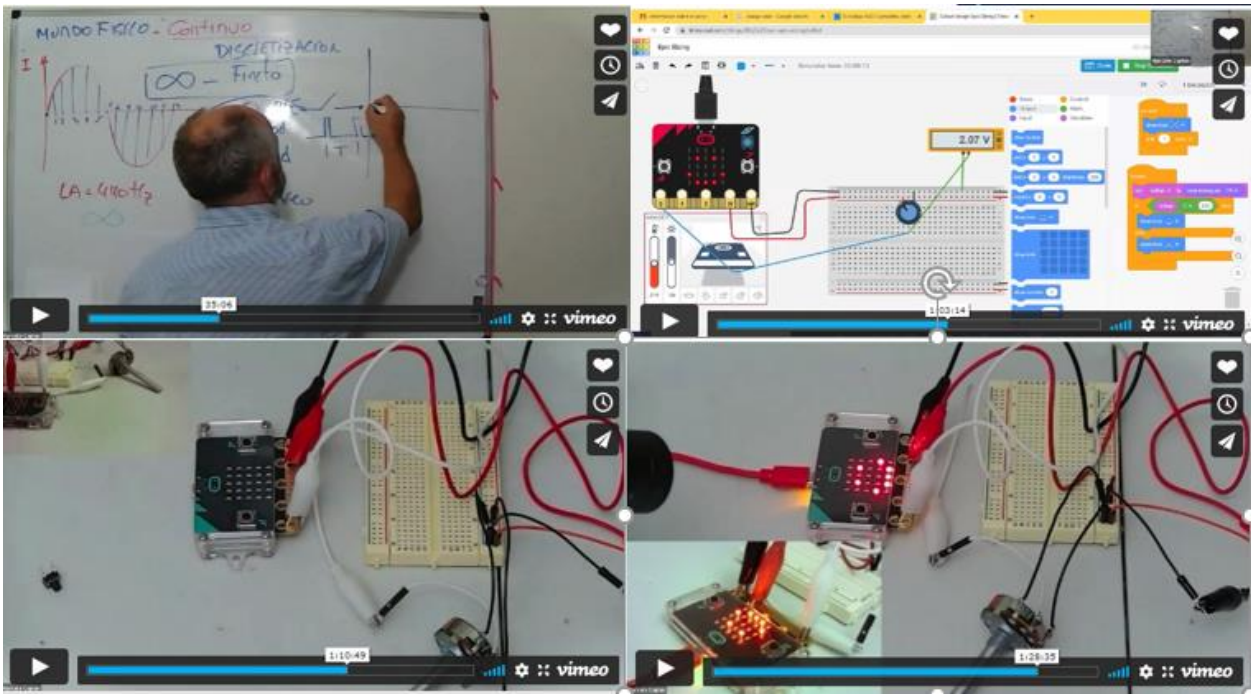

Figure 8. Images of what the student **sees** when participating in the STEM remote learning session

2) The participants have access to the communication and the materials required to implement the activities and the projects.

Below is a list of several programs implemented by the Author through remote learning.

Introduction to Computational Thinking: implemented with several teachers and students in school sessions. These ten synchronous sessions took place with students and teachers in Peru, Colombia, Mexico, and Argentina.

The Physics of Sound and Mathematics of Music were implemented with teachers and students in Argentina. This course includes four synchronous sessions.

STEM Education for All: this course introduces STEM education for teachers. The course had eight synchronous sessions and ran with the support of the Universidad Autonoma de San Luis de Potosi, Mexico, and teachers' participation in several Latin American countries.

La Hora STEAM [15] this program developed by the team Manifiesto STEAM provided access with equity to non-privileged groups in Latin America.

Global STEAM Academy: under the leadership of Aaron Cortes from CCAS-NEIU, several teams of students from the USA and other countries in Latin America are learning about App developments and Solving problems using microcontrollers generating projects through international collaboration.

Final remarks

It is abundantly clear that the pandemic Covid 19 substantially impacted our lives in general and in the education field. The pandemic placed the educational systems in a permanent crisis mode, and these systems are struggling to accomplish their goal amid uncertainty and difficult decisions to make.

The alternatives of remote learning presented in this manuscript are a tentative solution to provide students and teachers with a way to learn and continue their professional and educational path despite the limitations. Under any circumstances, this paper tries to prove that these methodologies are better than others or that they are tested enough to establish their validity (or not). These presented alternatives are the reaction to a change in the needs. Therefore, these new needs started the development of the technological approach; in search to find alternative solutions that students and teachers can incorporate to adapt to the changes in the learning environment.

The learning environment has changed radically, and therefore we need to find new tools and inventions to adapt to the changes. Furthermore, the instructors and researchers need to change and adapt to the new learning environment and not only discuss about it.

The product of a reaction, remote learning, needs to be tested, and therefore the educational community needs to continue developing and improving the remote learning strategies. The Author believes that remote learning strategies will remain in place after the pandemic vanishes. Therefore, the educational system needs to invest time and effort in incorporating remote learning as one of the valid strategies to promote learning in our communities.

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Appendix #1 – List of Tools and Materials

Item #	Quantity	Description
1	6	Rechargeable AA batteries
2	1	Battery Holder for 4AA batteries (Jameco)
3	1	Battery Holder 2AABatteries (electric cart)
4	2	diode 1Amp
5	1	6V Solar Panel
6	1	Breadboard
7	1	Roll of wire
8	30	Resistances 220 ohms
9	5	RED LED
10	5	YELLOW LED
11	5	GREEN LED
12	1	Buzzer
13	4	SPDT switches
14	1	Set of tools
15	1	Multimeter
16	1	Cardboard Knife
17	2	Cardboard Box large
18	1	Hot glue gun with glue sticks
19	1	4 feel heat shrink tube 1/16
20	1	4 feet heat shrink tube 3/32
21	2	UV LED
22	2	Coin Battery
23	10	Wood Popsicles
24	1	copper tape
25	10	Small rubber bands
26	1	insulating tape
27	1	yellow highlighter
28	5	Black paper
29		Week 4
30	1	page with a protractor
31	4	wheels
32	4	connector beams
33	2	dowel 5mm
34	1	Slide stop
35	1	gear motor
36	1	USB male-female extension