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Abstract. In this study, the authors present the utilization of laboratory-based Learning at the University of Parma and its integration with DigiLab4U (Open Digital Laboratory for You). At the University of Parma, the course of AUTO-ID in production and logistics from the very beginning has exploited the lab-based learning to convey practical skills gained in RFID (Radio Frequency IDentification) Laboratory to the students through a hands-on laboratory. However, due to the COVID-19 pandemic and consequent measures taken by the Italian government, the very same method could not be used anymore during the spring semester of the year 2020. To solve the issue a batch experiment method has been adopted, where the parameters were set by students and the experiment was carried out by a researcher. During the experiments, the researchers gather raw data and send it back to the students. Having these data, the students were able to perform the data analysis. To give the students the possibility to better understand the environment of the laboratory, pictures, and videos of the experiment performance have been supplied too. To complete the batch experiment, a tutorial has also been provided with the details of the software set up and the components used. The total remotization of RFID Laboratory is scheduled for late 2021.

Keywords: Lab-based Learning, Auto-ID, Batch Experiment.

1 Introduction

Since October 2018, when the DigiLab4U project (http://digilab4u.com) has seen the light, the five universities of the consortium (University of Parma, HFT Stuttgart, IWM Koblenz-Landau, BIBA Bremen Institute for Production and Logistics, and RWTH Aachen University) have started to work on the experiments' scenarios. The mission of the project is to provide a common platform of hybrid education and research in non-traditional laboratories for the Internet of Things technologies in cross-institutional cooperation. In Parma, the collaboration involves the course of "AUTO-ID in production and logistics", which is addressed to the students of master's degree in management engineering. The course takes place in a spring term and consists of face-to-face lectures and practical experience, during which, originally, the students used to go to the

RFID Laboratory of the University of Parma to run practical tests. Through the collaboration with DigiLab4U, the RFID Laboratory started organizing itself towards its automation stage to become remotely accessible in order to enable the students to perform experiments without a physical presence. The lab is planned to be fully available by remote starting from the year 2021. In the meantime, teaching should have continued commonly. However, due to the COVID-19 pandemic crisis, the presence of students was strictly prohibited. To cope with the situation and give the possibility to learners to continue gaining practical experience, a proper solution has been found. The University of Parma provided the online theoretical lessons for the students and together with DigiLab4U elaborated a batch experiment method. In "batch experiment" students fully specify the experimental conditions in advance and submit the specification as a request. The experiment is then performed according to student's specifications [1] and raw data are shared with them for further analysis.

The goal of this work is to report an application of the batch experiment methodology, which might enable students to remotely perform lab activities without utilizing a remote lab. In this way, the benefits of lab learning might be collected by students even without physical interaction with the lab. To prove the applicability of our method we report a case study carried out at the University of Parma during the year 2020.

The remainder of the paper is organized as follows. In section 2 the authors will provide a literature review on the batch experiment utilization, the hands-on and remote laboratories, the utilization of documents, videos, and pictures as a tutorial for the students, and the modification had in lab-based teaching due to the COVID-19 pandemic. In section 3 the structure of the AUTO-ID course will be presented together with the experiments that were originally performed in the RFID Laboratory. Section 4 will follow with the arise of COVID-19, the design, the implementation, and the deployment of batch experiment methodology. Sections 5 and 6 will close the paper with the discussion of the results and the future steps.

2 Literature review

The paragraph discusses the importance of laboratories and hands-on experiments in STEM (Science, Technology, Engineering, and Math) disciplines. Hands-on experience helps to obtain applicable knowledge that students will use in practical situations. Hence, the lab is essentials in university education [2]. Teachers and researchers use hands-on laboratories to run the didactical experiments. The laboratory's goal is to give the students the technical skills as well as the understanding of the process in the "real" environment. However, usually traditional labs have high costs as they require many essentials elements to be provided: (i) safety, (ii) large area spaces to provide observability, (iii) availability of the teacher. Ergo, many universities have started to use remote laboratories. In the literature, experts share different opinions about remote and hands-on labs. Remote laboratories have various advantages as (i) reusability, (ii) interoperability, (iii) convergence, and (iv) the possibility that the students use them independently [1]. Utilizing a remote lab may reduce expenses and save students time, as they can access to the experiments anywhere and anytime via internet. Moreover, it enhances the students' autonomy in understanding the experiment and its limitations. On the other hand, remote laboratories hardly support the development of collaborative learning skills. Indeed, teamwork is important during the laboratory's activities as well as the possibility to "watch" the crucial real experience. Thus, there is a need of maintaining a "blended-learning approach" which is a balance between two types of laboratories [3]. Remote laboratories are successfully used in universities to teach different topics. For example, in measurement engineering, the learners study the mechanical properties of materials where the remote experiment helps students to develop skills in a physical laboratory [4]. At the University of Tennessee, a remote chemistry lab is used. Here the students use web access to manage the laboratory stations. Separated into teams they control liquids flow and its physical properties. Students insert settings according to the objectives of their learning goals, then collect and elaborate data [5]. Some remote laboratories provide a data repository to collect experiments' data. For example, in iLab, students control the lab instruments by setting parameters. iLab is a network of remote laboratories, thus is possible to share resources between each lab. To do so, it provides data capability storage and other generic services [6]. Lab2Go repository focuses on creating a common framework to gather and analyze data of any laboratory in the world based on web technologies [7]. Lila is an online repository based on a meta-infrastructure, from which it is possible to download the resources from its web portal [8]. Another relevant lab-network is Labicom that is used for hosting and sharing online laboratories. It has three types of data: static client content, real-time data, and live streaming video [9]. The next lab analyzed is RemLabNet. It collects information under controlled values and measures data results to experiment with the same set up that can be reproduced offline. The system creates storage of all information and experimental data that are registered by users for later use. Moreover, the data warehouse is a part of a system storage and system central united data analysis for remote laboratories [10]. The last network analyzed is SCY (Science Created by You). SCY is a learning environment based on platforms where students learn about science topics resolving a socio-scientific problem. Students can save work in repository service and also, they can invite other students to work with them [11]. Due to the COVID-19 pandemic, universities were forced to search for new ways to teach practical courses. To continue the laboratory's activities Dept. of Engineering at the University of Parma, developed batch experiments. A batch experiment is an experiment where different settings are chosen in advance, then used to collect raw data. [12]. In this type of experiment students do not need to be present "physically" in a lab, however, can use data collected from real experiments previously. Being at home the students decide the parameters to be set, while a technician goes into the laboratory to run the experiment using the parameters requested. After that, a technician will send the raw data to the students. In this way, the students work on real raw data, analyze it, and reach the finals goals. For example, the University of Michigan uses the batch lab method. The university has created a remote chemistry laboratory for the student that should attend all subject in the laboratory. The teacher made use of a textbook with a web platform to select chapters and videos. Students, instead, used simulation software to create experiments and results, and at the end, they generated a video describing the experimental procedure [13].

3 AUTO-ID in Production and Logistics

It is strongly believed that a combination of theoretical and practical activities helps to assimilate studied cases [14]. The "AUTO-ID in production and logistics" course has always been taught as a sequence of face-to-face theoretical lectures and practical experience in the RFID Laboratory. The goal of the course is to teach the basic AUTO-ID technologies notions, with a focus on RFID, in the logistics and production systems. The theoretical knowledge provided by the course leads the students to acquire the skills needed to design an AUTO-ID solution in different application contexts. To enhance these skills, a practical experience completes the course. Here, the students are divided in groups of three or four people, and one scenario out of two is assigned to them. In the first scenario, the students must determine and analyze an RSSI (Received Signal Strength Indicator) curve of products having different RF natures (i.e. RF-friendly; -reflecting; -absorbing). The second scenario objective is to optimize the parameters of an RFID system to achieve the highest percentage of reads of wanted tags and the lowest of unwanted ones. Both scenarios are dived in different phases:

- **lab experience**, where students go to the RFID Laboratory, to set up the system with the supervision of an expert, run the experiment, and collect the data.
- **data analysis**, where the collaborative learning aspects, that represent a fundamental part of the engineering students' education [15], are used the most. The students discuss the future steps to be taken and then proceed with the data elaborations.
- **report creations and discussion**. In this final part, the students present the outcomes of the data analysis and discuss their conclusions with the professor.

Both scenarios are designed with the scope to introduce the learners to an industrial-like environment, allowing them to understand how to behave within a real production system, and how the acquired knowledge can be applied in practice. The RFID Laboratory consists of a circular structure equipped with an industrial roller, a belt conveyor, and three non-automatized roller conveyors that work as unload buffers. Moreover, two Near Field (NF) and two Far Field (FF) are installed on one side of the belt conveyor. To trigger the antennas' activation, a photoelectric cell is installed. All these five components are connected to a reader. The function of the reader is to link the antennas and the trigger to the reader's software installed on a PC. The software is used to select the antennas, set parameters (i.e. reading time, power level, trigger event), and collect the data from the antennas. To this end, different boxes are located on the conveyor and circulate on it, with the photoelectric cell triggering the readings of the antennas, and the reader setting the parameters and storing the data on the PC. To have an environment even closer to a real one, sixteen tags have been attached on a wall next to the antennas to simulate the bias noise (i.e. the presence of unwanted tags) findable in an industrial background, and some errors have been added to the RFID reads, as more external tags or extra number of cycles.

3.1 Scenario 1 “RSSI curve creation”

During the theoretical lessons, the students are taught about the theoretical RSSI curve trend of an RFID tag moving at a constant speed in an electromagnetic field [16]. The RSSI value is an indicator of the power present in a received radio signal and its theoretical value can be easily calculated. However, in an industrial facility, the RSSI curve is influenced by numerous factors, including the frequency and the surrounding environment. With this experiment, the students can elaborate an RSSI curve offline, which resembles the real-time measurement. Thus, the students reach the overall learning objective which is - compare the theoretical estimated curve with the practical one calculated during the data analysis.

Learning environment.

In the Design of Experiment (DOE) (Table 1) for the RSSI curve creation, there are three boxes containing the same product, running on the belt conveyor ring. Every time the three boxes complete a lap of the ring, a cycle is computed. The boxes run five cycles for each power level value, that equal to: 18 dBm, 21 dBm, 24 dBm, 27 dBm, and 30 dBm. This procedure is repeated for the products “A”, “B” and “C” (i.e. RF-friendly, RF-reflecting, RF-absorbing), and two types of antennas (FF and NF).

Table 1. - RSSI Curve Creation DOE

<table>
<tr><th>Products</th><th colspan="2">RF friendly</th><th colspan="2">RF absorbing</th><th>RF reflecting</th></tr>
<tr><td>Power (dBm)</td><td>18</td><td>21</td><td>24</td><td>27</td><td>30</td></tr>
<tr><td>№ of cycles</td><td colspan="5">5</td></tr>
<tr><td>Antennas configuration</td><td colspan="2">NF</td><td colspan="3">FF</td></tr>
</table>

During each cycle, once a box passes in front of the photoelectric cell, the reader receives a signal and triggers the activation of the antennas selected. Their active time is defined as a parameter of the reader. In the current experiment, the reading time was set at three seconds. Each of the nine boxes is labeled with a single Dogbone Paper Face Monza R6 tag. The three products inside the packages were: (i) oil - RF-friendly, (ii) canned tomato sauce - RF-reflecting, and (iii) bottled water - RF-absorbing.

Experiment execution

Before starting the experiment, the students were divided into groups of three to four people to enhance collaboration skills, fundamental in the engineering field. Thus, the students place the boxes on the circular belt conveyor with three meters between them. The PC is connected to the reader via Ethernet, and through the reader’s software the parameters are set. When a package passes in front of the photoelectric cell, the reader activates the antennas; the trigger time is t_0. The reader switches off the antennas at $t_f = t_o+3$ s. During these three seconds, the antennas stimulates the tag, collect data from them, and send the data through the reader to the PC. Here, once the five cycles are over, a .csv file is created. This file stores as many text strings as the number of reads. In turn, each string reports: Electronic Product Code (EPC) value, Time Stamp, Run

Number, RSSI, Reader, Channel, Power, and Antenna. Once the data collection process is complete, the students start the data analysis. Here, the data are organized and the RSSI curve is calculated in function of the time stamp. At this point a well understanding of the industrial environment is paramount - the students should be well oriented in the environment they worked in to interpret the obtained data correctly.

Final results

Once the data analysis will be made on all the products, power levels, and antennas configurations, the students will have 30 different configurations (three products for five power levels, and two antennas type) that have to be compared; the related outcomes have to be presented. To do so, the difference between transmitted and received power, the meaning and the factors that influence the RSSI curve, the reason for their impact, and the deviations of the real curve from the theoretical one, must be clear.

3.2 Scenario 2 “Reading optimization”

One of the main challenges in the RFID area, and especially in an industrial environment, is the configuration of the parameters that optimize the readings. During the lectures, the students are introduced to this topic with the calculation of α- and β-types errors. α-type error, or type-I error, denotes the percentage of tags that must be read but were not read during the reading time. It can be calculated with the formula (1):

$$\alpha - type\ error = n^o\ of\ expected\ tags\ not\ read\ /\ total\ n^o\ of\ expected\ tags \quad (1)$$

On the other hand, β-type error, or type-II error, indicates the percentage of unexpected tags that have been read on the total number of unexpected tags that must not be read. Its formula is:

$$\beta - type\ error = n^o\ of\ unexpected\ tags\ read\ /\ total\ n^o\ of\ unexpected\ tags \quad (2)$$

In our scenario, the total number of unwanted tags was 32, divided in 16 ghost tags attached on a wall near the belt conveyor, and 8 tags attached on each one of the two boxes not analyzed. The minimization of these two errors has to be achieved with an appropriate configuration of the input parameters (i.e. power level, type of antennas, and antennas orientation), which is the students’ final objective.

Learning environment

In this scenario, only one product (i.e. aluminum cans of tomato sauce) is present. Three boxes containing this product are placed on the belt conveyor ring, and, as in the previous experiment, a cycle is computed anytime a complete round of the ring is concluded. The DOE (Table 2) reports the configuration of the experiment: five cycles per power level, from 30 dBm to 18 dBm with a decrease of 1 dBm every five cycles. This procedure is replicated for four different antennas configurations: (i) NF parallel to the belt conveyor (scenario id: NF); (ii) FF parallel to the belt conveyor (FF-//); (iii) FF oriented 45° in motion direction (FF+45°); (iv) FF oriented 45° opposite to motion direction (FF–45°). Each box is labeled with eight Dogbone Paper Face Monza R6 tags, two on each side face, one oriented vertically, and another one horizontally[1], [15]. As for scenario 1 "RSSI Curve creation", the reading time was set at three seconds.

Table 2. - Reading optimization DOE.

Product	Tomato sauce (3 boxes)												
Power (dBm)	18	19	20	21	22	23	24	25	26	27	28	29	30
№ of cycles	5												
Antennas configuration	NF			FF-//			FF+45°			FF-45°			

Experiment execution

As previously, in this scenario the students are divided into groups of three to four people. The boxes are placed on the conveyor ring with a sufficient distance between them to avoid reading overlay. Time zero (t0) is taken as the moment when a single box activates the photoelectric cell, by passing in front of it, and consequently, the reader receives the signal and switches on the antennas. Starting from t0, the antennas are set in reading mode for three seconds (tf = t0+3 s). Here, the antennas transmit data to the reader, and then to the reader's software installed on the PC. The software allows the data exporting in .csv format as for the RSSI Curve Creation scenario, displaying the same data. With 52 .csv files (the combination of 13 power levels and four antennas configurations), the students start the data analysis. The learning goal of this scenario is to define the combination of power level and antennas configuration that minimizes both α- and β-type errors. To do so, the students must detect the box that activates the photoelectric cell. This box is labeled with eight tags that are expected to be read, while all the remaining tags read in the same run are to be considered as "noise" (unexpected tags). A tag is considered as "read" when it is scanned at least once by one of the two antennas. This analysis has to be repeated for all three boxes, resulting in three calculations of the α- and β-type errors. It is also particularly important for the students to identify all the tags and correctly map them to box A, B, C, or ghost reads.

Final results

The theoretical knowledge provided before the experiment will introduce the students to how the reads will change according to the different types of antennas or with a different antennas' orientation. Having both errors calculated for each box, power level, and antennas configuration, the students will be able to define the most effective combination of factors to minimize them.

3.3 RFID laboratory evolution

RFID Laboratory at the department of engineering and architecture at the University of Parma has been active since the year 2006 and became an experimentation station for RFID applications locally and internationally. Since the year 2018 RFID Laboratory has been added to the consortium of DigiLab4U project focused on providing a hybrid education platform. Thus, since then laboratory upgrade has taken place, which embraces various areas of the environment, i.e. hardware-software connectivity, learning environments, teaching scenarios. According to the plan, full remotization will be achieved by the end of the year 2021. In the meantime, the RFID Laboratory should continue functioning normally. However, the spreading of the COVID-19 pandemic has forced the Italian government to adopt critical countermeasures that made it impossible to perform the experiment on-site. As the RFID Laboratory is not remotely accessible yet, as proper connectivity hardware is missing as well as the software layer to manage it, as a middle step, a batch experiment method has been implemented. A batch experiment is an unforeseen solution to go up with an emergency situation. It will be taken out of the curriculum once the world pandemic situation comes back to normal. In the meantime, the laboratory upgrade is continuing as it was previously.

4 Batch Experiment

Ever since the pandemic has started the Italian authorities had to ensure students' school continuity to grant the students the possibility not to lose the 2019/2020 school year. Owing to the remote laboratory at the University of Parma being fully activated only next year, some specific techniques and actions were undertaken to continue long-distance lab education. The batch experiment is one of these techniques. The essence of the batch experiments was to give the students the possibility to define the parameters, thus enabling the DigiLab4U staff to go to the laboratory, run the existing scenarios according to the parameters set, and provide the resulting raw data to the students for subsequent analysis. The main challenges were: (i) to execute an experiment having absolutely new conditions; and (ii) to figure out how to remotely guide the students through the batch experiment. To this end the batch experiment was performed in three steps: (i) gathering parameters, (ii) collecting data, and (iii) analyzing data.

4.1 Data gathering

The first step requires the definition of the parameters by the students. After the gathering of the settings, the presence of DigiLab4U and the University of Parma staff in the lab is required to run the two scenarios. In case of a batch experiment, two full professors at the University of Parma and two members of DigiLab4U team were present in the RFID Laboratory to collect raw data. Preparation of the tests includes customization of the software, adjustment of the antennas, reader, and a photoelectric cell, placing the last one on a specific place depending on the configuration of each scenario. Additionally, one of the participants was asked to prepare the examined samples (see Tables 1 & 2) as well as to attach the required amount of tags on the boxes with those samples inside, and ghost tags on the wall near the antennas (as in Figure 1). The experiment was executed following exactly the same methodology as described in the previous sections. In both scenarios, anytime a box passed in front of the photoelectric cell, the reading round was triggered, and the reader received values of readings from both antennas. Due to the synchronization with the photoelectric cell, the reading rounds were not 'automatically' numbered by the reader; rather, this must be done by students, keeping in mind that the reads of each reading round were clustered in a time interval of max 3 seconds. A cycle, each of which counts 3 reading rounds, is defined by a box moving along the whole length of the conveyor, thus completing its tour. However, we noted that some reading intervals may last longer than the expected 3 seconds. This fact aims at simulating possible manual errors while performing the experiments. Students should therefore try to identify those errors and correct them. This correction may not have a significant influence on the overall result of this experiment, but it may be very educational to introduce this inaccuracy in the analysis.

4.2 Preparing materials

After running the tests, significant attention was given to the design of the learning materials. It was quite a challenge to form the studying sheets in such a way to (i) keep up the motivation of learners, even if they were not able to go to the lab personally; (ii) maintain their curiosity; and (iii) familiarize with how a semi-industrial environment works. Detailed learning sheets were developed to explain to the students the experimental setups, the tasks, and assignments, and recap the theoretical concepts. Additionally, the designed learning materials contained: (i) the motivations for the adoption of the batch experiment; (ii) the theoretical notes linked to each scenario; (iii) the preparation of the experiment; (iv) the materials and methods applied; and (v) an example of expected results. Videos, and other digital tools are certainly useful supplements for increasing classroom learning as well as equity, compensating for real-life obstacles to laboratory education. To create a more realistic picture of the laboratory, several detailed videos were therefore recorded. Those videos explain the structure of the laboratory and all possible experiment configurations to allow asynchronous instruction.

4.3 Batch experiment completion

As a second step, the material described above was uploaded on a common learning platform (Moodle) that was successfully adopted for assignments, logistics, and distributing course materials at the University of Parma. Consequently, students were seren-

Fig. 1. - Experiment configuration.

dipitously partially prepared for transitioning to remote learning. The collected RFID raw data was provided in .csv file format and was uploaded in that platform together with the learning materials. Students were separated into groups of two to three people and were advised to carefully study the materials before starting the experimental phase of the course. After this, each student worked on his/her own inside every single group, solving the given tasks. The students were free to choose by themselves how to elaborate the raw data and which data analyzing tool to use. As it is believed that teaching presence is a foundational concept of online education, and particularly the batch method, so the students were continuously supported by the tutor, who was available for a chat and/or videoconferencing to offer help and guidance. After finishing analyzing data, students were expected to create a report, according to the objectives of the scenario, and discuss it with the professor during the exam for the final evaluation.

5 Discussion

The approach presented in this paper enabled the possibility for the students to have a semi-practical experience. In that way, they have been able to apply the theoretical knowledge learned and face the difficulties of a real environment. This effort maintained the very same course format as the previous academic years, even with the use of different methods (i.e. e-learning, recorded videos, informative material, batch experiment). Moreover, from a didactical point of view, the authors: (i) analyzed the critical point of the learning materials when provided online without face-to-face lectures; (ii) introduced the tutor and analyzed the interactions of students with her; and (iii) adapted the data analysis to the workload required. Until now, lab-based learning has always been held with hands-on laboratory and the same should have been happened for the AUTO-ID course during the year 2020. However, due to the COVID-19 pandemic, a batch experiment approach was adopted. Such a way to resolve the occurred situation not only helped to continue lab-based education but also served as a starting point to prepare a blueprint for the future lab remotization. The authors suggest that utilizing a batch experiment may significantly reduce potential problems with the integration of lab scenarios, as those scenarios, together with supplementary materials, have been designed, tested, and improved to fit the online learning platform. The adoption of such a method is also a possible example of how to confront occurred circumstances in a short period and continue teaching. Using a batch experiment method promoted an opportunity to introduce the students to an industrial-like environment, and its peculiar characteristics, in a virtual way, while still complying with the COVID-19 crisis. Such an approach is obviously a temporary solution to go up against the pandemic situation, however, can be furtherly used as an emergency measure in case of hardware/software malfunctions or to comfort an individual request of a student or a teacher. In Table 3 can be saw the characteristics of the different type of laboratory.

From a practical point of view, the students were evaluated by completing an online exam and succeed quite well. After the exam students participated in the evaluation of the new method. The interview structure was developed by an expert in evaluation, also a member of DigiLab4U, and contained both general questions and some particular information about the execution of the experiment. Students reported positive feedback.

By acknowledging that the students' suggestions to improve the experimental design were valid and worth pursuing, we raised the chances that they will remember what they learned and be able to transfer it to novel problems in the future.

Table 3. - Different type of laboratory characteristics

	Hands-on laboratory	**Batch experiment**	**Remote laboratory**	**Virtual laboratory**
Environment Interaction	Real environment	Videos, pictures, files	Webcam, videos, AR/VR[1]	Virtual /Simulated
Parameters customization	Full	Limited	Full	Partial/Full
Data gathered	Real	Real	Real	Simulated
Availability	On booking	Always	On booking	Always

6 Future steps

We are now working on making the lab available for remote access in the nearest future, with a planned hardware upgrade of the lab by the end of 2020, as the first step of its complete remote automation expected by 2021. Towards this goal, our future step will be the upgrade of the software layer linked to the laboratory hardware. By following those steps, and improving the existing scenarios, the AUTO-ID course will be accessible from all over the world, trough the DigiLab4U Learning Management System, and will be enriched by new technologies and alternative teaching methods.

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