Available online at http://www.journalijdr.com

IJDR

ISSN: 2230-9926

International Journal of Development Research
Vol. 11, Issue, 06, pp. 48183-48189, June, 2021
https://doi.org/10.37118/ijdr.2263.06.2021

RESEARCH ARTICLE OPEN ACCESS

OPEN PLATFORM FOR BUILDING, DEPLOYING AND MANAGING REMOTE LABS

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ARTICLE INFO

Article History:
Received 25th March, 2021
Received in revised form
27th April, 2021
Accepted 11th May, 2021
Published online 30th June, 2021

Key Words:
Educational Technology,
Remote Laboratories, Open Source,
Open Modular Platform.

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ABSTRACT

This article presented an open platform for building, managing and deploying remote labs. Its development is supported by open educational resources, free software, and open hardware. The verification of the platform was performed in three scenarios that used remote laboratories. Courses in the distance learning modality, higher education and basic education, including technical education, were used. The methodological choice for the development of the platform used the Design Science Research method. The evaluation was performed from two scenarios: one built from experts with recognized experience in the research area and another with potential users, to understand the acceptance of resources and tools. The first included an experimental evaluation from experts in the field of research. And a second group where questionnaires were applied that sought the respondent's perception about the experience and use of remote laboratories. The questionnaires for this group included items related to usability, learning perception, usefulness, and satisfaction. The questionnaires were answered by 86 experts from 31 countries, who gave an average grade of 7.96 for the three remote laboratories evaluated. From the second group, 995 students participated in the research. The results showed that the proposed platform makes it possible for institutions to make available resources through the construction of remote laboratories. For students and teachers, it is an opportunity to take advantage of existing connectivity by making use of available computing resources, especially mobile devices, enabling them to perform their practical activities via the Internet.

Citation: Juarez Bento da Silva, Simone Meister Sommer Bilessimo, Leticia Rocha Machado, Ladislei Marques Felipe Castro and Isabela Nardi da Silva 2021. "Open platform for building, deploying and managing remote labs", *International Journal of Development Research*, 11, (06), 48183-48189.

INTRODUCTION

This paper focuses on the integration of technology in education, to provide computational resources to support course formation, especially in STEM areas. There is a recurring need for the formation of qualified professionals, especially in the technological and engineering areas, who can contribute to the solution of current and future problems. This qualification decisively involves students performing practical / laboratory activities. The "open platform" is a modular software and hardware infrastructure for building and deploying remote labs online (RL). Its development is supported by open educational resources, free software, and open hardware. In terms of use, its application is mainly in the STEM areas. Since it can reach all school levels, resources and services can be applied to Basic Education, Technical Education, and Higher Education. Considering Brazil, potential users of the products and services generated by the available technology can be categorized as follows:

- Support for courses aimed at STEM areas, in the distance learning modality;
- Support for classroom teaching in Higher Education;
- Support for classroom teaching in Basic Education and Technical Education.

To support STEM courses in distance learning mode, RLs can provide improvements in products, processes and the creation of a new service, for example, to provide laboratory practices via the Internet. Data collected in the e-MEC System (http://emec.mec.gov.br/), on 23/05/2020, showed the existence of 556 courses in the areas of engineering and 236 courses in Physics, Chemistry and Biology, all in EAD mode. Making a total of 637.846 and 307.503 authorized vacancies, respectively. The resources and services provided by the presented platform for these courses can contribute to answering questions about the impossibility of approaching certain subjects in an e-learning modality, as they provide Internet access and overcome space-time barriers, for people and resources. They also aim to optimize laboratory materials and

human resources to reduce investment. In higher education the study of many theories can be facilitated by the use of simulators, although some physical experiments are also performed, simulations have largely replaced them because simulations are much cheaper than laboratory devices. Certainly, simulations are great tools for learning theories and models, as they have no noise or other imperfections in the models, and will not hide the expected result. However, students, for example, from STEM subjects should spend part of their time conducting physical experiments so that later, as professionals in the labor market, they could understand the nature and details of the models used in the real context. The practical components of today's labs in many institutions are insufficient to allow educational institutions to provide professionals with this capability. Thus, generally, the solution is to privilege the theoretical component of formation over the practical component. Thus, it is necessary to overcome the challenge of providing educational environments that provide more access to practical activities. Remote labs (RLs) contribute to overcoming this challenge through a new approach and tools for practical activities, presenting itself as an important support tool for classroom teaching, assisting teachers in their practices. In addition to the notorious and well-known laboratory infrastructure shortfalls, the use of mobile remote experimentation can add extra resources beyond the classroom. Since its resources are available 24 x 7, minimizing the space-time barrier. Also, its use through mobile and conventional devices should be highlighted (Silva*et al.*, 2014).
The third scenario proposed, and perhaps the most complex and certainly the most important is related to basic education. At this educational level, experimental activities inspire teens and young people to practice science, technology, engineering and math, as well as providing tools for teachers to make their classes more attractive and aligned with the real world (Silva *et al*., 2014).

For example, young children conduct rudimentary experiments to learn about the world. Over time, most of them enter the virtual world and gradually live much of their time in it. It is not difficult to realize that many young people find the virtual world more exciting than the school environment they attend, because they perceive it is far from the world in which they live. There is a need to have more attractive teaching and learning environments and not considering this, may imply the demotivation and disinterest of students, especially in the STEM areas. For example, basic theories and mathematical models of natural phenomena are presented in a "traditional" way (concepts presented in oral sessions), and the complementation of this formation should take place through the use of physical experiments conducted in instructional laboratories. However, the availability of laboratory equipment is poor or non-existent in many elementary schools (Silva *et al.*, 2014). Table 1 presents data from the 2020 Census of Basic Education in Brazil.

Table 1. Technological resources in basic education schools in Brazil

Resources	Public	Private	Total
Computer Lab	34%	35%	34%
Internet/Broadband	61%	86%	66%
Science Lab	9%	22%	12%
Average computers for student use by school.	6,73	9,79	7,41

Source: Censo Escolar da Educação Básica/INEP 2020

Taking advantage of existing connectivity and making use of available computing resources, especially mobile devices, enables teachers and students to find virtual experiments and access remote labs via the Internet. Many educational institutions now offer virtual experiments and a variety of labs that support remotely operated physical experimentation. Figure 01 shows the possible laboratory configurations for practical activities, mainly in courses in the scientific-technological and engineering areas. In a remote lab, user can work with equipment and devices and observe activities through a webcam, mobile or computer, giving students a real view of the behavior of a system and allows them to access resources available in a remote lab from anywhere and anytime (Silva *et al.*, 2014). Traditionally, in schools and universities, students perform individually or in groups a series of hands-on physical experiments during a laboratory session that takes place in an instructional laboratory. The experiments are supervised by an instructor who prevents students from performing dangerous experiments that could damage them. These labs are available to students only when an instructor is present. Remote labs, on the other hand, are operated remotely over the Internet, but actual experiments take place in the room where the experimental equipment is located. Most of these labs are available 24 hours a day, 7 days a week (Silva *et al.*, 2014).

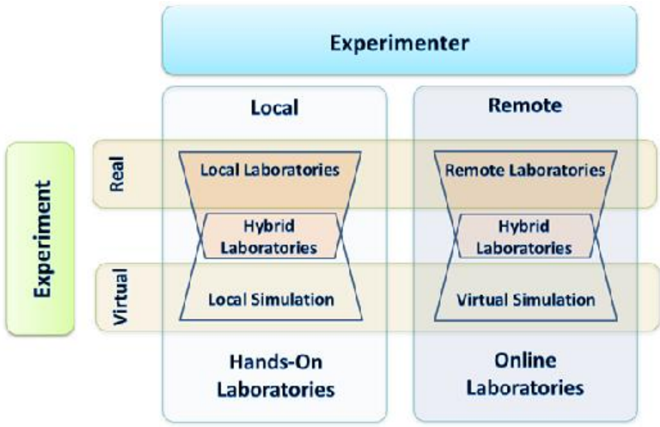

Figure 1. Remote and Virtual Labs. Source: Zutin *et al* (2010)

Remote experimentation (RE) may develop the capabilities of understanding a problem, simplifying and modeling the problem, formulating hypotheses, methodological proposition, hypothesis verification, making measurements, data analysis, concluding, among others. However, conducting experimental activities in elementary education is extremely limited. One of the reasons that makes it so difficult is the high cost required for the implementation and maintenance of laboratories in schools. Also, the number of students in this type of laboratory is very restricted and depends on someone to monitoring the practices (Silva *et al.*, 2014). The resources and services provided by the developed platform are focused on the integration of technology in education. In particular, the use of remote laboratories, as a tool to increase the quality of students' practical training, especially in STEM subjects. Emphasizing that the use of mobile devices and existing connectivity meets current educational demands. Because digital technologies are an integral part of the society we live in and have impacted on people's way of life (Silva *et al.*, 2014). In a world where smartphones, notebooks and many computing devices surround people's activities, they inevitably need to reach the educational realm. Thus, there is an increase in the number of educational opportunities for students in diverse environments, increasing interest, especially for their mobility, ease of communication and content sharing. Anatel data indicate that Brazil ended in April 2021 with 242.1 million cell phones and a density of 113.615 cell / 100 hab.The TIC Domicílios survey (http://www.teleco.com.br/internet_usu.asp) conducted in Sep / Oct 2020 indicated that 92% and 99% of people in the age groups 10 to 15 and 16 to 24 years, respectively, had accessed the Internet in the last 90 days. This opens a great opportunity for the technology presented here, as remote laboratories favor interaction with real processes and allow the user to analyze practical problems in the real world, even if they are far from the laboratory.

The methodological option for the development of the platform was Design Science Research (DSR), which is a research method centered on the evolution of a "design science". Lacerda *et al*. (2013) say the DSR focuses on the importance of defining problem classes and artifacts generated in the research scope. Aken (2004) says that problem classes can consist of an organization for the trajectory and development of knowledge in design science. For Bax (2015), the DSR is a meta-theory that helps the researcher to create theoretical knowledge during artifact design processes, justifying how such processes can be significant for the scientific community. According to Hevner (2007), DSR is used for the development of information systems. According to this author, the knowledge required to research information systems involves the paradigms of "behavioral science" and "design science". Behavioral science address research by developing theories that explain phenomena related to identified business needs, and design science addresses research by developing and evaluating artifacts designed to meet the identified business need. In this document, we present the methodology and aspects related to the construction of the open platform, without the concern of being too technical and also the scenarios and data obtained for its verification. These include experts, for technical verification and usability, learning perception, satisfaction and usefulness, for users in the three proposed use scenarios: distance learning, higher education and basic education.In the following sections, we present the methodology employed, the open software and hardware platform developed, the obtained results and the conclusions.

METHODS AND MATERIALS

This research was oriented towards the search for an archetype (model) to support the construction and implementation of remote laboratories in educational contexts. The research methodology used was the Design Science Research (DSR). The DSR aims to build scientific knowledge by generating an innovative artifact that will try to answer relevant questions of some problems of human reality. An artifact that can be a theory, method, model, software, process, etc.(Gregor &Hevner, 2013;Hevner& Chatterjee, 2010; Vaishnavi, Kuechler&Petter, 2004).Thus, DSR can be defined as a research tool to create innovative artifacts that help solve or improve on real problems, i.e., its purpose is to create new means to achieve some general goal, thus creating a new reality rather than explaining the existing reality or helping to make sense of it (Livari & Venable, 2009). Figure 02 presents the steps followed in the research.

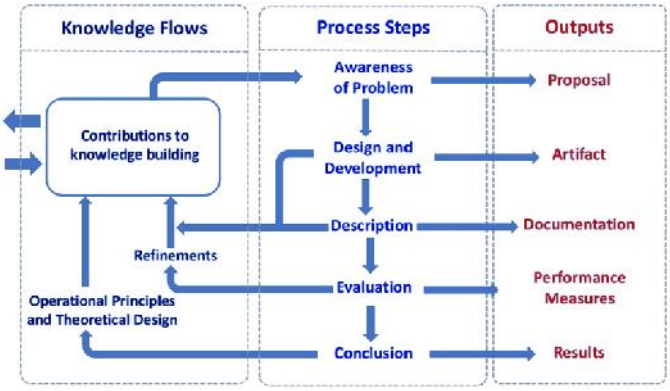

Figure 2. Scheme of the research process. Source: Adapted from Vaishnavi, Kuechler & Petter, 2004)

Identification problem: The goal of DSR research is to develop technology-based solutions to important and relevant business and social issues. According to Vaishnavi, Kuechler&Petter (2004), as the objective of this methodology is to create or invent an artifact that does not exist, it can be developed regularly, if the researcher already knows to create it. The contextualization of the problem is represented in the Introduction section, where it is presented and how it is intended to contribute to the solution. The identification of the problem is reflected from the perception of the opportunity of the development of remote laboratories, development of open modular architecture (artifact) with wide potential for use.

Development: DSR-based research predicts the development of artifacts, which may be theories, methods, models, software, processes, etc. Depending on the type of artifact, the implementation resources that correspond to each case must be employed.Therefore, for this research, the desired artifact consisted of an open modular platform for building and making remote laboratories available. For the development of the platform three basic premises were established: the first one was based on open educational resources, free software and hardware. Thus, this would be favoring the reapplication of the products and services developed. The second is that the developed technology would allow remote labs to be built according to user needs. The third is to prioritize cost reduction. Thus, was conceived a model based on free software and hardware that would allow the integration of its elements in a way that would allow the construction of new remote laboratories, instead of developing it "from scratch". Also, this design has advantages such as reducing time and costs due to the reuse and/or modification of existing software and hardware resources, and this also represents an advantage in the speed of development. It is important to highlight that due to the characteristic of the research, the reuse also presupposes the possibility of modifying the resources (always preserving the use of licenses assigned to them), as well as incorporating new elements required for the desired purpose.

Description: The description of the artifact is the part where the DSR presents the biggest difference compared to other research methodologies. This step consisted of describing the artifact in detail in its options and features. In addition to the open availability of all documentation related to software, hardware and educational content (technical manuals, application manuals, user guides, etc.).

Evaluation: In the DSR methodology, evaluation represents a vital aspect. Therefore, the artifact must be evaluated, in laboratory tests or through field research, among others (Gregor&Hevner, 2013). The mode of evaluation will depend on the type of artifact generated, the method of development employed and the research objectives. The objective of the research was the development of a platform for technology integration in education. In line with the DSR, the research, although covering the construction of software and hardware individually, is focused on the built platform and mainly its use. Thus, the evaluation was performed from two scenarios: one built from experts with recognized experience in the area of research knowledge and another with potential users to understand the acceptance of services, resources and provided tools. The first consisted of experimental evaluation from experts in the research area. The technical and functional aspects were the object of the experts' evaluations and their contributions provided the refinements for resource improvement. The second consisted of an evaluative profile tending to the observational from the user experience about usability, learning perception, usefulness and satisfaction, by the three focus groups of research (students of distance learning, higher education and basic education), presented in the introduction section. Regarding the experts, a questionnaire called "Evaluation of remote laboratories" was applied in online and digital formats, which was preceded by an invitation letter. The questionnaire has seven questions related specifically to remote labs available for analysis (CC Panel, AC Panel and Metal Bar Driving).

The recipients of the questionnaires were contacts identified based on RExLab's participation in related events (International Conference on Remote Engineering and Virtual Instrumentation (REV), Experiment@International Conference (Exp'at), IEEE Global Engineering Education Conference (EDUCON), ICBL , International Conference on Blended Learning (ICL), Technological Ecosystems for Enhancing Multiculturality (TEEM) and Congress of Technology, Learning and Teaching of Electronics (TAEE) and also for the IEEE group that deals with IEEE-SA P1876 WG standardization.This IEEE Working Group, called the "Networked Smart Learning Objects for Online Laboratories Working Group" (NSLOL WG), discusses the IEEE P1876 ™ standard for intelligent networked learning objects for online labs. The proposal is "to facilitate the design and implementation of pedagogically conducted remote laboratory experiments and their learning environments". Regarding potential users, the evaluations took place in elementary schools and in higher education institutions, through the "experimental classes", while in the distance learning courses, 300 invitations were sent to the coordinators of the Open University of Brazil poles, presenting the environment and requesting that information was passed on to students, preferably from undergraduate courses. These invitations were sent through CAPES, which facilitated access to the poles. The evaluation process in EAD modality was performed using an online questionnaire, called "The evaluation of the use of remote experimentation", which was completed by students after access to one or more remote laboratories available, to collect their perceptions about the experience. The questionnaire consisted of two parts, the first part tried to identify the characteristics of the study sample, verifying the profile of the subjects involved in the research. In the second, the perception of respondents about the use of remote laboratories was sought. This part was structured with 24 questions stratified into four subscales, 6 referring to usability, 6 regarding the perception of learning, 6 about the satisfaction of use and 6 regarding the utility of the tool.It was used a 5-point Likert scale (Lindsay, 2005) to calculate the satisfaction scores, consisting of several elements in the form of statements, on which they should have expressed their degree of satisfaction, and the following values were adopted for the analysis. Numbers: 1 strongly disagree (SD), 2 partially disagree (PD), 3 no opinion (NO), 4 partially agree (PA), 5 strongly agree (SA). The internal consistency of the instrument applied was measured, the alpha coefficient was calculated, which is currently the most used statistic to measure the reliability of a questionnaire. For purposes of analysis, we conceptually define the subscales as follows:

- **Usability:** basically, related to the functionality and availability of remote laboratories;
- **Learning Perception:** about students' perception regarding the improvement of learning from the use of the remote laboratory in the didactic activity;
- **Satisfaction:** related to the educational resources added to the learning process;
- **Usefulness:** associated with motivation and satisfaction for learning. Besides the interest in repeating the experience.

An online questionnaire was applied for higher education, similar to that applied to the distance learning modality. This questionnaire was structured based on the questionnaires developed by the authors mentioned above. Consisting of 23 items, which were divided into four subscales: Usability (5 items), Learning Perception (6 items), Satisfaction (6 items) and Utility (6 items), which try to understand the degree of agreement of students regarding the used technology.

The questionnaire applied to high school students, similar to the higher education questionnaires, had 23 multiple-choice items, was made available online, and tried to evaluate the satisfaction regarding the use of remote laboratories in the lesson plans by the students through factors such as usability, learning perception, satisfaction and usefulness.

Conclusion

In DSR the process is finalized with the conclusions as with other research methodologies, but unlike the others and similar to what happens in the evaluation phase, the conclusions can also mean only the end of a cycle and not the end of the investigation (Vaishnavi, Kuechler&Petter, 2004). According to Vaishnavi, Kuechler&Petter (2004), an operating principle can be defined as “a technique or frame of reference related to classes or artifacts, or features that may facilitate the creation, manipulation, and modification of forms of the artifact”. In this case, the availability of documentation and instructions for the construction and availability of RLs in open environments presented the research results.The socialization of research is also related to this phase through publications, presentations of works, etc.

RESULTS AND DISCUSSION

Developed platform: A fundamental component for the development of this type of platform is the creation of a RLMS that provides a common framework for accessing and managing different laboratories that offers some services such as scheduling, user tracking and synchronous communication tools (Orduña*et. al.*, 2016). Many studies argue that RLMSs should be independent of the design of the remote laboratory to support as many remote laboratories as possible (Lowe*et al*., 2016; Garcia-Zubia*et al*., 2016; Lowe*at al.*, 2009). RLMSs are responsible for managing the interaction between all components and interfaces of a system. Based on the works of (Maiti*et al*., 2018; Gomes & Bogosyan, 2009), a typical RLMS must contain these components:

1. Concurrency control - interactions with experiment hardware need to be coordinated because online users are not aware of each other's activity within the system. There are at least two concurrency control strategies used: queue and scheduling.
2. Operation on the equipment - the laboratory consists of a set of devices or instruments controlled by a computer. In this case, the RLMS sends requests and receives data from the experiment.
3. User interface - users often interact with the experiment through a web browser, but other customers, such as games and mobile apps, are also possible. User interfaces allow the user to observe, interact and control the equipment, as well as acquire data and results.
4. Request processing - users have limited control over features and accepted entries. In the request processing, the validation of the inputs is performed, as well as functions that deal with the logic of the application are triggered. This component provides an interface for user integration, usually over a protocol supported by most client applications, such as HTTP or WebSocket.
5. Data and/or tools about the experiment - any information necessary for the user to understand and analyze the data of the experiment. Live video streaming, for example, is a tool used to observe a certain visual change.
6. User management - user information is stored and manipulated to perform authentication and authorization tasks.

RExLab has developed and implemented a platform that integrates a virtual learning environment, online learning content and remote labs. The objectives of this platform include expanding access to remote labs and encouraging technology integration for primary and secondary school teachers and students.The core of the platform is formed by the remote labs and the Remote Labs Learning Environment or simply RELLE [http://relle.ufsc.br]. These two components include remote labs, services and applications that provide web access support for mobile or conventional devices. They also provide remote labs control, observation and access to educational content on computational multi-platforms (Silva, Bilessimo & Alves, 2019). Currently 22 remote labs are available in 26 instances. Following is a description of the implemented architecture, explaining its elements and the infrastructure required for its implementation. All remote lab builds were implemented based on the standard architecture, hardware and basic software. The difference between the remote lab can be seen in the different types of sensors and actuators, which were installed according to the specificities of each remote laboratory.The platform architecture was divided into three modules: Remote Laboratory Management System (RLMS), Laboratory Information System (LIS) and Laboratory, as shown in Figure 03.

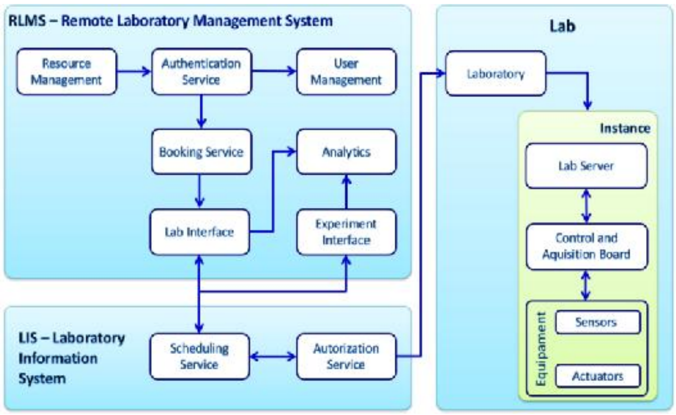

Figure 3. Platform Architecture for RL. Source: Authors

The RLMS module is made up of seven blocks as named and characterized as follows:

1. Resource Management: Responsible for providing laboratory-related teaching materials, such as manuals, teaching sequences, tutorials, videos, simulations, etc. The student learns the theory through teaching materials and runs the experiment on the same platform. This platform can be accessed using a tablet, smartphone or computer through a web browser.
2. Authentication Service: Responsible for authenticating users using local user credentials, federated authentication, or social login. This method applies cryptographic mechanisms to give privacy to users who access remote experiences.
3. User Management: Responsible for handling local users, such as creating or deleting users, changing the password for existing users, etc.
4. Scheduling Service: Provides an interface that allows users to book a lab at a specific date and time. This service reserves the resource (remote lab) for a private user over a specified period. If the user does not perform their activity within this time frame, any other user can do so, and the feature becomes available.
5. Lab Interface: Provides a front-end interface that allows users to access and interact with labs, controlling experiments and displaying related statistics from the analysis module.
6. Data Analytics: takes care of log aggregation, generating laboratory access statistics.
7. Experiment Interface: Provides user interaction with an experiment in an available lab.

The Lab Information System (LIS) module consists of two blocks as named and characterized as follows:

1. Scheduling Service: is responsible for managing who has the right to access the experiment at a given time. Every user who wants to access the system must have lab access authorization.
2. Authorization Service: Verifies if the user who wants to access a lab at any given time is valid (if they have the correct passkey).

The Lab module consists of three blocks as named and characterized below:

1. Lab Server: Contains two different and independent software layers: logical access and network. The first layer provides lab-specific functions and features that can be reused. The second layer is responsible for exposing operations on physical equipment using WebSocket. All layers follow the event orientation paradigm.
2. Acquisition and Control Board: Consists of an electronic circuit developed by RExLab (see Figure 11) for operating sensors and actuators through an API for communicating with the hardware. This API is responsible for communication between software and hardware. Each equipment (actuator or sensor) must use this API. In this block, specific functions of each remote laboratory are implemented, such as input parameter validation, programming and access time to sensors, sending signals to actuators, experiment status tracking, and hardware exception handling.
3. The Equipment block: is the hardware itself composed of sensors, actuators, displays, etc., that make up the remote laboratory.

Figure 04 shows the acquisition and control board, developed by RExLab and available in open hardware mode, used in remote laboratories.

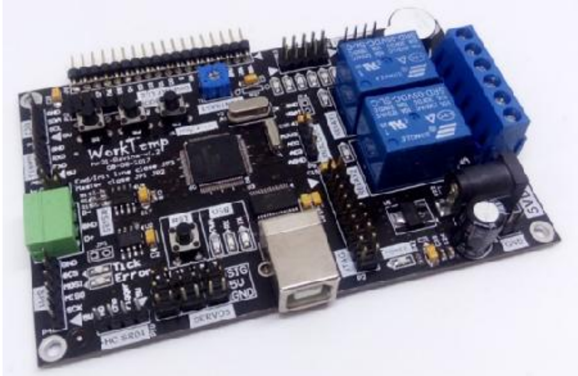

Figure 04. Acquisition and control board. Source: Authors

All remote labs use the same basic architecture. In each of them, the acquisition and control board are responsible for receiving/sending signals from sensors and actuators and transmitting then to the embedded computer that manages the experiment by the developed application. The electrical diagram of these boards and the use of each RL is described in the technical manual documentation. The design of control and acquisition boards, as well as the design of sensors and actuators, was developed by RExLab to reduce its dependence on proprietary solutions and to fit the needs of each experiment.

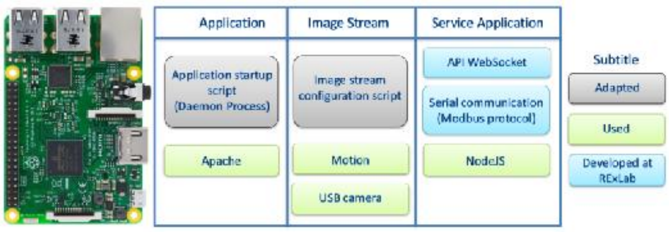

Figure 5. Lab block overview. Source: Authors

The Raspberry Pi embedded computer was chosen to be part of the platform. This choice is due to the presence of features similar to desktop computers, such as Linux operating system support, as well as the low cost and ease of purchase of the device on the marketplace.Technical documents (electrical diagrams, printed circuit board layout, etc.), documents for assembly of existing laboratories (mechanical design and cutting diagrams of the various parts) were provided to facilitate

Platform evaluation: The objective of the research was the development of a platform for technology integration in education. Lined up with the DSR, the research, although covering the construction of software and hardware individually, is focused on the built platform and mainly its use. Thus, the verification of the platform was performed in real use scenarios and also in consultation with experts worldwide spread in the areas of virtual and remote laboratories, mobile learning and e-learning regarding the usability and potential use of resources and services provided by the platform.
The questionnaire applied to high school students tried to evaluate the satisfaction regarding the use of remote laboratories in the lesson plans by the students. 541 high school students, from 2017 to 2018, from four public schools, in the municipalities of Araranguá/SC, BalneárioArroio do Silva / SC and Uberlândia/MG, answered the questionnaire. The Cronbach's alpha coefficient for the questionnaire applied (23 items) was 0.87 (Internal consistency value "Almost Perfect" according to Landis and Koch (1997). Likert scale was 4.06, the standard deviation for the item average was 0.31 and the coefficient of variation was 7.74%. Figure 06 graphically presents the values of the mean scores for the four scales evaluated. From the Likert scale used, with five levels of satisfaction, it can be observed that two values (utility and learning perception) reached rates higher than 4 and two (usability and satisfaction), values close to 4. It is possible to state that the results obtained for the four sub-scales are in agreement with the statements.

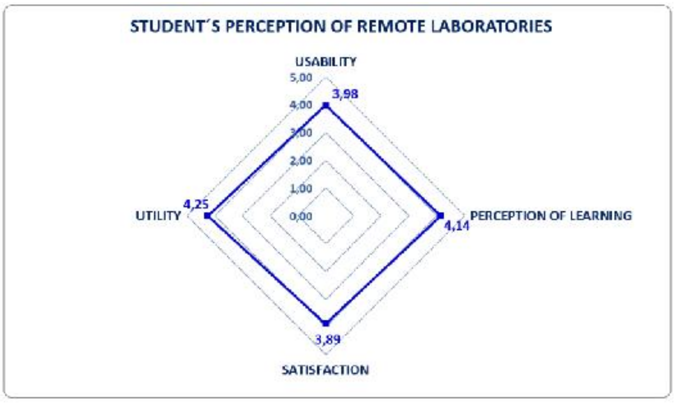

Figure 6. Scores for the questionnaire subscales. Source: Authors

Higher Education Results. The questionnaire was answered spontaneously by students who used the remote labs to support their classroom practice. One hundred and sixteen (116) students from engineering courses from 2017 to 2018 from three public higher education institutions answered the questionnaire. The average score on the Likert scale was 4.14, the standard deviation for the average of the items was 0.344 and the Cronbach's alfa coefficient of variation 8.31%. The Cronbach's alpha coefficient calculated for the questionnaire applied, in its total (23 items), was 0.85. For the sub-scales was Usability = 0.62 (Substantial); Learning Perception: 0.57 (Moderate); Satisfaction: 0.72 (Substantial) and Utility: 0.67 (Substantial). Figure 07 graphically presents the mean score values for the four scales evaluated. From the Likert scale used, with five levels of satisfaction, it can be observed that two values (utility and learning perception) reached rates higher than 4 and two (usability and satisfaction), values below 4. It is possible to state that the results obtained for the four sub-scales are in agreement with the statements.

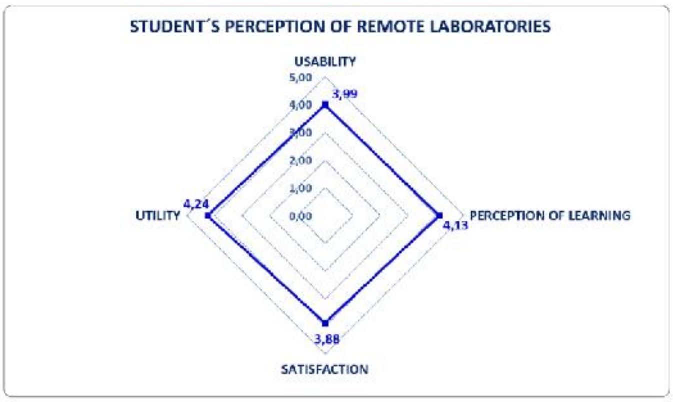

Figure 7. Scores for the questionnaire subscales. Source: Authors

Higher education distance learning results. Data collection was performed between April 2018 and August 2019. The questionnaire was made available on the RELLE platform, which is the access environment for remote RExLab laboratories. The questionnaire was applied spontaneously and had 292 answers. However, for this analysis, data were extracted from 259 higher education students, in the distance learning modality, who were able to know and contribute opinions about the experiments available in RExLab and their perception about remote experimentation. Table 02 presents the profile of the responding students. More than 90% were students of Degree and Pedagogy courses.

Table 2. Profile of respondent students

Profile	Abs	%
Bachelor / Pedagogy Student	235	90,73%
Engineering / Computer Student	13	1,93%
Student Administration / others	5	5,02%
Total	259	2,32%

Source: Censo Escolar da Educação Básica/INEP 2018

The most accessed experiment by the respondent students of the research was the remote microscope with 35.52% of the results, followed by Newton's disk with 18.92% of the accesses.The average score on the Likert scale for the 24 items analyzed was 3.98, the standard deviation for the average of the items was 0.358 and the coefficient of variation 9.01%. The Cronbach's alpha coefficient calculated for the applied questionnaire, in its total (24 items), was 0.97 and for the sub-scales was Usability = 0.66 (Substantial); Learning Perception: 0.95; Satisfaction: 0.94 and Utility: 0.92. Figure 08 graphically presents the mean score values for the four scales evaluated. From the Likert scale used, with five levels of satisfaction, it can be observed that three values (utility, learning perception and satisfaction) reached rates higher than 4 and one (usability), value below 4. It is possible to state that the results obtained for the four subscales are in agreement with the statements.Figure 24 shows the percentages for the questionnaire sub-scales. Grouping the answers obtained for CT + CP and DT + DP, excluding the values attributed to “without opinion”. We have: CT + CP = 69.4% for satisfaction; 69.0% for learning perception; 62.6% for usability and 74.4% for utility.

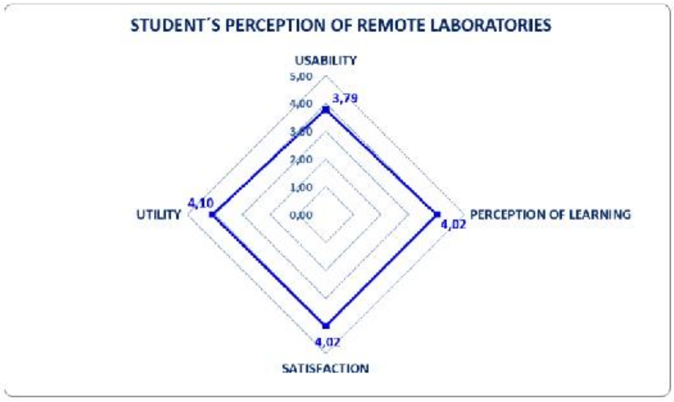

Figure 8. Scores for the questionnaire subscales. Source: Authors

CONCLUSION

This paper aims to present an open platform for the construction, management and deployment of remote laboratories. These laboratories are intended for practical activities, mainly in the STEM areas. The developed platform can reach all school levels. The provided services and resources can be applied from basic education to higher education. Experimental activity is one of the key aspects of science teaching and learning processes, both for the theoretical foundation that can contribute to students and for the development of certain skills for which experimental work is fundamental. There are arguments in favor of laboratory practices in terms of their value for enhancing the objectives related to conceptual and procedural knowledge. Laboratory work supports and promotes learning in the scientific-technological and engineering areas, as it allows students to question their knowledge and confront them with reality. In addition, the student places the previous knowledge into practice and verifies it through practice. Therefore, the experimental activity should not be seen only as a knowledge-building tool, but as an instrument with the potential to promote the conceptual, procedural and attitudinal objectives that should include any pedagogical content. The lack of technological infrastructure in public institutions in Brazil, greatly aggravated in basic education, does not provide satisfactory environments for the achievement of practical activities. In this context, LRs appear as a real possibility, since they are devices that can support experimental activities, and contribute significantly to the improvement of teaching and learning processes, especially in STEM areas. With a glimpse of the potential use of LR, the modular open platform was developed and made available. The validation, for user purposes, was performed in three educational scenarios, with great potential for use (courses in STEM areas for distance learning mode; higher education and basic education).

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