Remote labs in high school: a case study in physics teaching

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***Abstract*— This document explored remote laboratories (LR) and their potential for practical activities in Physics in high school. LRs are devices that can support experimental activities, which are one of the key aspects of science teaching and learning processes. The research, with a qualitative approach, used a case study as a strategy. Participated in the research, carried out in 2017, 2 teachers, and 454 students, from 13 classes, from a public school in Uberlândia/MG. The collection was carried out through two questionnaires, one directed to the students, composed of 25 items, distributed in the subscales: usability, learning perception, satisfaction, and usefulness. The second, composed of two open questions, was applied to teachers who participated in the research. The average Likert score for the 25 items was 3.94 and the Cronbach's alpha coefficient found was 0.85. The interpretation of the data showed that the perception, on the part of students and teachers, that the remote laboratories showed benefits to the study of Physics. Making it possible to harmonize theory with practice, mainly due to the lack of laboratory infrastructure in public schools. Participants also highlighted the possibility of carrying out practices at any place and time.*

***Keywords*— Educational Technology, High School, Physics Teaching, Remote Laboratories.**

I. INTRODUCTION

Scientific training, in the opinion of many experts, is a requirement that has been demonstrating its strategic role in the development of people and peoples. Scientific training or culture must be acquired from the first years of schooling and, especially, before dropping out, as in many countries, such as Brazil, there are high rates of dismissal before the completion of high school.

According to data released by INEP [1], failure and/or dropout rates were 6.0%, 12.9%, and 16.9%, respectively for elementary, middle, and high school. Since the 9th grade had a dropout rate of 7.7%. Significant percentages if it is taking into account that in 2017 Brazil had over 35 million students enrolled in elementary, middle, and high school.

In addition to the indexes presented, account should also be taken of the dropout in the transition from the last year of middle school to the first year of high school. There are several causes that cause evasion, and will not be addressed in this document, however, meaning, flexibility, and perception of importance also represent factors that contribute to this. Many adolescents and young people have the feeling that the school is not adequate to their reality and vision of the future and start to consider it “as a waste of time and end up preferring to dedicate themselves to other things” (Meaning). They do not perceive the school as dynamic or innovative if they engage less in school activities (Flexibility). The perception of importance, on the other hand, emphasizes that education and school must not only teach relevant topics but also motivate students and show that what the object of study is or will be useful for their life, that is, presenting education as a value.

It is observed that the deficit in science education goes far beyond the fact of learning or not learning scientific content. This deficit will also condition the full exercise of that person's citizenship. Another face for the same problem is in a scientific education that no longer arouses interest, pleasure, and motivation for learning science. If this situation persists, students will lose their attraction to scientific and technological careers.

This context reinforces the need for more attractive environments for teaching and learning, redesigning education, creating new and interesting teaching and learning opportunities. That is, to provide compatible, non-antagonistic environments, with the way, especially children, adolescents, and young people learn. For example, using the Internet, mobile devices, and virtual and remote laboratories in the educational context.

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 improving objectives related to conceptual and procedural knowledge. Aspects related to scientific methodology, to the promotion of reasoning skills, specifically to critical and creative thinking, and to the development of attitudes of open mind and objectivity and distrust of those judgments that lack the necessary evidence [2].

Laboratory work favors and promotes science learning, as it allows students to question their knowledge and confront them with reality. Besides, the student puts previous knowledge into practice and verifies it through practices. The experimental activity should not be seen only as a knowledge tool, but as an instrument that promotes conceptual, procedural, and attitudinal objectives that must include any pedagogical device [3].

However, most Brazilian public schools do not have laboratories equipped to carry out experimental activities. According to the School Census of Basic Education MEC/INEP 2018, only 11% of schools in Brazil (8% public and 19% private) had science laboratories. Also, according to the MEC/INEP 2018 School Census, only 38% of schools (38% public; 37% private) had a Computer Laboratory and the average number of computers available for use by students in schools was 7.41 computers per school. for student use (6.7 public and 9.7 private).

These are shortcomings that have led to deficiencies in technological infrastructure in basic education schools. What hinders the integration of digital technologies in the educational context. And consequently, create opportunities for the creation of compatible environments, not antagonistic, with the way, mainly children and adolescents learn.

According to the CoSN Driving K–12 Innovation/2019 Tech Enablers report, the main technological tools with the potential to facilitate the path to broader opportunities and solutions in education for the next five years are Mobile devices; Analysis of learning and adaptive technologies; Blended Learning; Extended reality and Cloud computing infrastructure. And the estimate of adoption by schools worldwide, on a scale of 1 to 5 (1 = the most immediate adoption; 5 = the most distant from adoption) was estimated as follows: 1.26: Mobile devices; 1.41: Blended Learning; 1.58: Cloud Infrastructure; 2.48: Extended Reality and 2.49: Adaptive Analysis and Technologies.

The CoSN Driving K–12 Innovation/2019 report highlights the emphasis on Internet-based technologies. Mobile devices, such as smartphones, allow access to information and creative activities anytime, anywhere. Mobile devices also support global connections, self-capture content, and personalized learning. Making it possible to extend not only the classroom but also the school. That is, not limiting the teaching and learning processes to the time and space of the classroom. In a concept of ubiquity [3] referring to a society that learns and absorbs data and information all the time and everywhere. It also has a direct effect on the way teaching and learning should be viewed in this context.

Data from the National Telecommunications Agency (Anatel) indicate that Brazil ended April 2019 with 228.6 million cell phones and density of 108.71 cell phones/100 inhab. Regarding the use of these devices, data from the Teleco portal, for 2017, identified the following profiles: Percentage of people in the age group who accessed the Internet in the last 90 days: 10 to 15 years old = 91% and 16 to 24 years old = 96%; Internet Users by Income Range: up to 1 SM = 60%, 1SM - 2SM = 72%, 2 SM - 3 SM = 79% and location used for access by Internet users: At home = 94%, at school = 19 %, workplace = 19% and someone else's home = 62%.

These data show opportunities for using mobile devices, especially smartphones, in an educational context. The expansion of the educational space allows students to see the school in very different places in their learning journeys. And that contemplates different needs, styles, interests, and preferences. The use of Internet-based resources. The Internet offers a large number of didactic alternatives that, with the necessary adaptations to the realities of each school scenario, can be used to promote the development of the cognitive process. These possibilities include, for example, videos, websites, interactive activities, content sharing tools, and online labs. Laboratories that have the potential to represent learning opportunities, and even fill gaps in infrastructure deficiencies.

The online labs include simulations (virtual labs), where it is possible to reproduce any type of experiment, without restrictions and real experiments (remote labs), whose interaction is intermediated by an ICT, where the student can manipulate real materials and equipment in a different place from found (Silva, 2018). In an online

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laboratory, the investigation parameters can be manipulated and the effects of this manipulation are observed to obtain information about the relationship between variables in the conceptual model underlying the online laboratory [4].

Inspired by the contextualization and problematization presented, this research was designed, which is based on the following premises: there is a need for more attractive environments for teaching and learning, in basic education; the growing use of mobile devices and the Internet by children and adolescents; and the lack of technological and laboratory infrastructure, mainly in public primary schools.

Seeing this scenario as an opportunity, the use of remote laboratories (LR) in Basic Education was proposed. An LR is characterized by online access to a real experiment. [5]

This document presents research developed over the academic year 2017 and which contemplated the use of LR, in Physics classes, in high school, in public schools. Two professors of the Physics discipline participated in the research, who made the specification of the resources and produced the didactic contents to be made available in the virtual learning environment (AVA) and 454 of the high school. Technical support and provision of digital resources were provided by the Campus Araranguá Laboratory. The research subjects were students, who took the Physics disciplines, in classes of 1st and 2nd years of high school, in the public system. The research involved 8 classes from the 1st year, totaling 262 students and 5 classes from a total of 192 students.

Following are the methods and materials, the main results, discussion of the results and conclusions obtained from the research carried out.

II. MATERIALS AND METHODS

Qualitative research in education allows using many methods to collect data and information, through personal experience, interviews, texts on the subject to be investigated, among others. Case studies are a very important research method in the development of human and social sciences, and represent one of the natural ways in research-oriented from a qualitative perspective [6]. According to Stake [7], case studies are an adequate method for investigation when it is in harmony with the researcher's previous experience. And this facilitates the understanding of the phenomena in question through an in-depth view of one or more cases during a defined time, to understand aspects of social behavior and the factors that influence the researched situation [8].

The population object of this study was the students who used the digital resources available and the teachers who boosted the didactic experience in their subjects. To select the sample and define the units of analysis, the object of the study, the following criteria were applied:

- Schools that are part of the InTecEdu Program developed by at RExLab since the research is linked to the use of remote laboratories, in Physics subjects, at EB, in a public school;
- Active teachers, teaching Physics, in basic education in the public network.

Based on the prerequisites defined above, three steps were taken to continue the research, which is described below:

1. Identification of the EB school: contacts with the physics teachers of the school in which the proposed research was developed, to present the work proposal and obtain approval of the discipline's coordination and effective agreement by the school's management in its development;

2. Strategy: definition of the teaching strategy for the use of technological resources;

3. Selection and availability of remote laboratories: carrying out a study of the remote experiments available at UFSC's RExLab, to identify the most appropriate ones for use in research.

The tools used for data collection were two questionnaires called: "Questionnaire for the evaluation of the use of mobile remote experimentation" and "Questionnaire of teaching reports regarding the use of mobile remote experimentation". The “Questionnaire to assess the use of mobile remote experimentation” was applied online for students. This aimed to observe the perception of students involved in research regarding the use of resources offered by LR, in the discipline of Physics. This questionnaire was structured with 25 (twenty-five) items, and was based on questionnaires developed and used by Professor Euan David Lindsay [9], from Curtin University in Australia, published in the document “The Impact of Remote and Virtual Access to Hardware up on the Learning Outcomes of Undergraduate Engineering Laboratory Classes ", as well as the study by Sergio López; Antonio Carpeño and Jesús Arriaga [10], from the Universidad Politécnica de Madrid, published in the document “Remote Lab eLab 3D: An immersive virtual world for electronic learning”.

The 25 items are divided into four subscales: Usability (7 items), Perception of Learning (6 items), Satisfaction (6 items), and Utility (6 items), which seek to perceive the

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degree of agreement of the students concerning the technology used. For the calculation of satisfaction scores, a 5-point Likert scale was used, formed by several elements in the form of statements, on which the degree of satisfaction must be expressed, and to perform the analysis, the following values were adopted in numbers: 1 totally disagree (DT), 2 partially disagree (DP), 3 without opinion (SO), 4 partially agree (CP), 5 totally agree (CT).

To estimate the reliability of the questionnaire applied in the research, Cronbach's alpha coefficient was used. This coefficient measures the correlation between responses in a questionnaire, by analyzing the profile of the responses given by the respondents. This is an average correlation between questions [11]. Cronbach's alpha coefficient is a commonly used measure of reliability (that is, the assessment of internal questionnaire consistency) for a set of two or more construct indicators [12]. Alpha values range from 0 to 1.0; the closer to 1, the greater the internal consistency of the items analyzed. The reliability of the scale must always be obtained with the data of each sample to guarantee the reliable measurement of the construct in the concrete sample of investigation.

The use of reliability measures, such as Cronbach's alpha, does not guarantee unidimensionality to the questionnaire but assumes that it exists [13]. As a general criterion, George and Mallery [14] recommend the following indications for assessing Cronbach's alpha coefficients:

- Alpha coefficient> .9 is excellent;
- Alpha coefficient> .8 is good;
- Alpha coefficient> .7 is acceptable;
- Alpha coefficient> .6 is questionable;
- Alpha coefficient> .5 is poor;
- Alpha coefficient <.5 is unacceptable.

The second questionnaire was applied to teachers who used the resources in their classes and comprised two open questions in which teachers were invited to indicate "strengths and weaknesses regarding the use of mobile remote experimentation in the science subjects taught".

III. RESULTS

The research was developed throughout the academic year 2017, in 13 classes of the subject of Physics, in classes of 1st and 2nd years of high school, in a public school in Uberlândia/MG. There were 8 classes from the 1st year, all from the morning period, with a total of 262 students and 5 from the 2nd year, all from the afternoon period, totaling 192 students. Therefore, the research had the participation of 454 students. The classes participating in the research were chosen according to the work plan defined by the teachers, together with the integration of the remote laboratories available. However, the definition of remote laboratories was by the content covered in the classroom.

Based on the criteria determined in the methodology section and others explained above. Remote laboratories were selected: "Conversion of Light to Electric Energy", for the 1st year classes, to work on the study of "Light energy (Interaction of radiation with matter)". For the 2nd year classes, the LR "Heat conduction in metal bars" was selected, to work on the theme "Heat propagation by conduction in metal bars".

The remote experiment "Conversion of Light to Electric Energy" aims to show the transformation of light energy into electrical energy, "using an automotive filament lamp and a photovoltaic cell". Next to the structure, "a capacitor and a resistor were added, allowing tests of the capacitor's charge and discharge times according to the amount of energy produced". This experiment contains "a photovoltaic fixed on top of a servo motor, which allows the user to move the plate close to or away from the light, and with that, respectively generating more or less energy". This "power generation can be verified through a multimeter and an LED matrix, where the light intensity generated by this panel is directly proportional to the energy produced".

Figure 1 shows the user interface for the LR Conversion of Light Energy into Electric Energy.

Fig. 1: LR Conversion of Light to Electric Energy

The LR "Heat conduction in metal bars" consists of three heat sources, one for each metal bar and three horizontal metal bars (Aluminum, Copper, and Iron) of 12.70mm x 4.76mm ". "Each of the metal bars has three temperature sensors spaced every 10 cm and three displays, which provide a temperature reading on each sensor along the bars".

Figure 2 shows the LR user interface "Heat conduction in metal bars".

Fig. 2: LR Heat conduction in metal bars

The "Questionnaire to assess the use of mobile remote experimentation" was answered by 260 students, representing 57% of the total enrolled in the Physics discipline. To interpret the results obtained in the questionnaire, the Average Score (EMd) was made and defined for the answers acquired in the questionnaire, using the 5-point Likert scale. To find out, if attitudes were positive or negative, through EMd, the following conditions were imposed: values below 3 presented adverse attitudes and greater than 3, favorable, while value 3 was estimated "without opinion". Thus, the EMd score for the 25 items was 3.94. Indicating a very favorable activity. The Cronbach's alpha coefficient found for all items in the questionnaire was 0.85. The Standard Deviation for the average of the items was 0.45 and the Coefficient of Variation was 11.51%.

Regarding the subscales, the average scores, on the Likert scale, were as follows:

- Usability: 3.68;
- Perception of Learning: 4.03;
- Satisfaction: 3.87;
- Usefulness: 4.26.

Figure 3 shows, graphically, the EMd values obtained for the subscales.

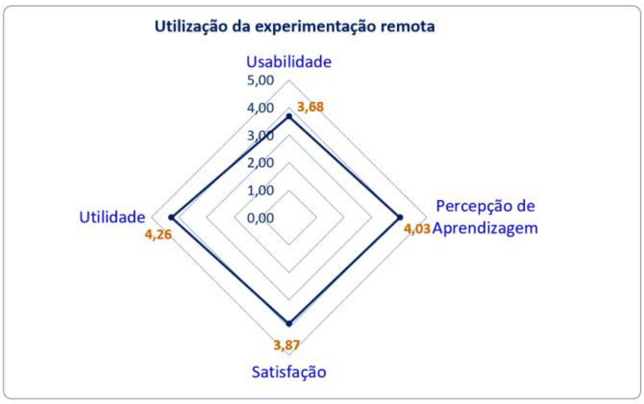

Fig. 3: Scores for the questionnaire subscales

Usability refers to the ease of use of LR. If there were no problems to perform the desired actions if the information on the screen contributed to handling the LR, and if the time available to execute and manipulate the experiment was sufficient to carry out the activities. The EMq obtained for the seven items was 3.68. About the statements, the lowest score was found in item 3 ("the internet connection made access to the remote laboratory difficult", with 2.61 and the highest in item 5, with 4.20 ("the information contained in contributed to handling the experiment").

The Perception of Learning sought to indicate whether the student, through the LR, perceived improvement in his learning, and whether the practice performed contributed to problem-solving if the concepts that were addressed during the use of the tool were understood, and these were related with the student's daily life. And, if "all the skills acquired were valuable for learning". The EMq for Learning Perception for the six items was 4.03. Regarding the statements, the lowest score was found in items 9 and 12, with 3.92 ("remote experimentation helped to relate the concepts studied in the classroom with my daily life" and "the acquired skills were valuable for my learning ") and the largest, in item 10, with 4.16 (" the remote experiment contributed to my learning ").

Satisfaction seeks to show how much the student "was convinced that he was carrying out a real and not remote experiment when manipulating the experiment, as well as if it is possible to achieve learning similar to that acquired in a classroom laboratory". Besides, it sought to show whether the student's ability to access the LR, at any time and from any place, was useful to better plan study time, and whether the tool provided new ways of learning. The EMd calculated for the perception of satisfaction about the six items was 3.87. Regarding the statements, the lowest score was found in item 19 ("the remote experiment improved communication with my colleagues") with 2.93 and the highest in item 18 with 4.51 ("I would like to use other remote experiments in the discipline of physics").

The Utility subscale sought to show whether the student "was more motivated to learn after using the LR, as well as whether he was satisfied with the experience". And, if "after using the LR, the student would advise other colleagues to use it as well, as well as if he would like to use other remote experiments". The EMq of the perception of Utility for the six items was 4.26. Regarding the statements, the lowest score was found in item 20, with 3.89 ("I was convinced that I was carrying out a real and not remote experiment") and the highest in item 25, with 4.60 ("the laboratory of remote experimentation can provide new ways of learning").

The second questionnaire was applied to the two teachers who participated in the application of resources in their classes. These were the two open questions in which the teachers indicated the "strengths" and "weaknesses", perceived by the use of remote laboratories in their classes. The following are some responses from the teachers:

Regarding the strengths:

- "The experiment has real physical existence and that is why it allowed us to deal with real problems in its handling";

- "Makes experimental activities possible, even without the presence of a science laboratory in the school";

- “Resource that facilitates the student's visualization; helps the teacher to transmit the material”.

As for the weaknesses:

- "The queue generated for the use of the experiment was the biggest obstacle".

- “I would quote the waiting line, but this can be circumvented with parallel activities. Another problem would be the connection to the internet, but it is also not a problem of experimentation, but unfortunately for the municipal and state public schools that lack this resource. So, I don't see any weaknesses”;

- "A student's waiting time to experiment, the queue".

IV. CONCLUSION

This document aimed to present a case study on the use of remote laboratories, for practical activities in the discipline of Physics in High School, in a public school. The objective was fulfilled and the results obtained in the data collection instruments were favorable to the use of the resources provided by the LR to support the experimental activities. The LRs provided students with remote access to physical experiments and their handling, without restrictions on time and place. It is also worth remembering that this technology has provided new ways of learning outside the classroom. Also, the classes were more interactive, dynamic, and attractive, and this made the students more attached to the discipline - the usual classes were switched. For example, the Utility subscale had a mean score of 4.26. Added the options Totally Agree (CT) and Partially Agree (CP), these reached 82.34%, for a sum of 6.38% Totally Disagree (DT) and Partially Disagree. Since the item with the highest average score, with 4.60, was where the students expressed their agreement to the statement that “the remote experimentation laboratory can provide new ways of learning”. In this item 93.53% of the students indicated (CP + CT) and only 2%, DT + DP. Another subscale with a very significant mean index was "learning perception" with 4.03. Where 86.15% of students indicated (CP + CT) and only 6.14%, DT + DP. In this subscale, the item with the highest score, with 4.66, was where the students were asked if “the remote experiment contributed to my learning”, where 94.53% of the students indicated CP + CT. These are results that allow us to reflect on the potential of digital technologies and their potential to contribute to education. However, the real potential of these technologies lies effectively in their integration into the teaching and learning processes. Integration that necessarily involves the role of the teacher when inserting them in their pedagogical practice. And providing a significant gain in the teaching and learning processes, and motivating students for new practical experiences in the classroom, bringing them closer to the real world.

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