A Model of Mediation in Remote Experimentation

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Abstract—**This is a Full Paper on Research-to-Practice that presents the result of the application of a mediation model to the teaching-learning process of kinematic concepts in remote experimentation. Kinematics was proposed for the development of the work, as it deals with fundamental concepts of Physics, which is a science directly related to STEM education. For the execution of the model, a remote access laboratory was designed, implemented, and evaluated. The model was applied to high school Physics students and can be extended to other levels of education. The remotes interactions followed an organization proposed by the mediation model. The research was based on the mediation of Vygotsky and Zone of Proximal Development. The system has been tested and evaluated by students and teachers.**

Keywords— model, mediation, Vygotsky, kinematic concepts

I. INTRODUCTION

Experimental practices are crucial in certain fields of knowledge. In areas related to Technology and Engineering, the experimental practice has a fundamental role to strengthen the understanding of the basic concepts obtained in class [1]. However, due to the pandemic situation caused by the SARS-CoV-2 coronavirus, carrying out the experiments in physical laboratories has become impractical in recent years.

Remote access laboratories have become a viable alternative for carrying out experimental practices at a distance and have proved to be quite useful for Engineering Teaching and related areas. A remote lab is a software and hardware artifact that allows students to interact with devices located elsewhere on the Internet [2]. Students work on real tools and components controlled from anywhere over the Internet [3]. Currently, remote laboratories or weblabs are widely used in engineering education because they present greater flexibility in access than a real laboratory [4].

Certain remote laboratories depending on the technology used, measurement conditions and configuration can expand the possibilities of carrying out experiments. Having chosen suitable measurement and configuration conditions, experiments for advanced topics in Electrical and Electronics Engineering are possible [5].

Another benefit made possible by remote experiments is the reduction of costs with materials and maintenance, as remote laboratories allow the sharing of resources between users and institutions [6].

Because remote access laboratories have numerous advantages, they have been the subject of research worldwide, the low cost related to obtaining and implementing it is one of the main benefits when compared to traditional physical laboratories. Virtual and remote labs can reduce expenses related to equipment, space and staff needed in hands-on labs [7].

The problem addressed in the work is the way in which the interactions between student, content, experimental practice and teacher are carried out. It is necessary to reflect and seek teaching and learning strategies to be implemented for this reality, in order to obtain a better use by students and teachers. In this sense, the article presents the result of a research carried out with the objective of studying and understanding a mediation model for the teaching and learning process of scientific concepts carried out during remote experiments. To this end, a Remote Access Physics Laboratory (LARF) was developed as a tool for the study of kinematic concepts that would allow the execution of the elaborated mediation model. The abbreviation LARF was obtained in Portuguese.

The mediation model in remote experimentation was applied to high school students in the discipline of Physics in the topic Kinematics in a state public school of Manaus (State of Amazonas, Brazil). During the execution of the research, diversified data and information were collected and later analyzed, obtaining a positive result for the application of the mediation model.

This article has the following organization: Section II shows the nature of the research and the theoretical foundation. Section III presents the Remote Access Physics Laboratory (LARF), the Mediation Model in Remote Experimentation and the assessments applied to students. Section IV presents the evaluation results. Section V shows the conclusion.

II. METHODOLOGY

A. Nature of Research

An applied category research was developed to solve a specific problem that was to determine an effective model for the interaction between student, content and teacher, ending with a Mediation Model in Remote Experimentation for the study of kinematic concepts. For [8], applied research is designed to improve the quality of practice in a discipline.

The study had a descriptive qualitative approach, as it presented characteristics that refer to this classification. According to [9], qualitative research has the natural environment as a direct source of data and the main instrument is the researcher. It is descriptive, the interest of qualitative researchers is more in the process than in results and products. The tendency is for data analysis to be inductive. In the qualitative approach, meaning is of fundamental importance.

The research was carried out in a natural environment that is the school space, where data collection was carried out using different tools, observations, questionnaires and tests. The information collected allowed for a detailed description of the mediation process and analysis of the results. In addition, the meaning given by the students to the process, expressed in responses, calculations and opinions, was essential for the conclusion of the research.

Observations were unsystematic and participatory. Questionnaires, pre-test and remote post-tests were applied, composed of open and closed questions about kinematic concepts. The post-tests were developed during remote experimentation, applying the Mediation Model for Remote Experimentation.

The research participants were high school students from a state public school in Manaus. In the analysis of the results, a variation of the Technology Acceptance Model (TAM) was applied, followed by a graphical percentage study on the responses, as well as Bardin's content analysis.

B. Theoretical Foundation: Vygotsky's mediation and the Zone of Proximal Development

For Vygotsky, mental functions such as thinking, perception, attention and memory, first arise in an elementary form and are later transformed into their highest form. Mental functions in their most elementary forms are developed by natural development. Higher mental processes are converted from the fundamental through cultural development. For higher functions, self-managed stimulation or the design and use of artificial stimuli is the central feature that becomes the immediate causes of behavior [10].

The Zone of Proximal Development (ZPD) was a concept conceived by Vygotsky and corresponds to the distance between the Actual Developmental Level (ADL) and Potential Development Level (LPD). In ADL, the student solves the problem questions alone. In LPD, the help of people with more conceptual knowledge is needed for the resolution. From the knowledge of the levels (ADL and LPD) and the ZPD, it is possible to follow the student's interaction with the object of study. Monitor their experimental observations, analyses, calculations and problem solving, locating the student at the most appropriate level.

Mediation is the process of positioning oneself between the student and the object of study. It is possible to say that the role of the teacher has always been that of mediator between the student and the knowledge to be conquered. The teacher presents new concepts to the students, helps them to go through this new knowledge until they appropriate it [11].

Through the ideas presented by Vygotsky, the research was developed using artificial stimuli to establish mediation: tools (such as LARF and the Mediation Model), signs (such as language via chat in Moodle) and the teacher himself as a person able to mediate the process, by having more clarity about the contents taught, indicating the student's Level (ADL and LPD) and executing the mediation plan. In this way, the teacher supported the learning process, during the study of contents, resolution of questions, execution of experiments and clarification of doubts.

III. MEDIATION IN REMOTE EXPERIMENTATION

Initially, the project of the Mediation Model in Remote Experimentation was conceived, planned and generated. Likewise, a remote access laboratory for the study of physical concepts (LARF) was studied and developed to enable the application of the Mediation Model with students, illustrated in Fig. 1.

LARF was made available in the Virtual Learning Environment, Moodle, with all the diversity of materials: videos, texts, hypertexts, simulators and exercises on the subjects that made up the Physics lesson plan. The content was accessed through mobile devices by the students registered in the course.

A. Remote Access Laboratory for the Study of Physics

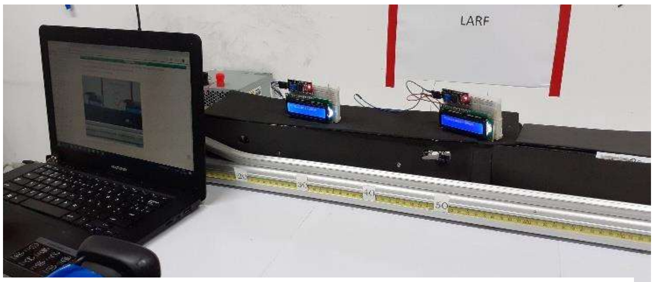


Fig. 1. Remote Access Laboratory LARF

Concepts (LARF)

The LARF consists of a set of apparatus and instruments for carrying out the experiments: a millimeter ramp with sensors that detect the presence of different moving masses. Arduino platform programmed in C Language for the detection of mass movements, interconnected to the sensors.

The entire structure of LARF with IP camera for recording, server and experimental apparatus was assembled in the Intelligent Systems Laboratory of Federal University of Amazonas.

B. The Mediation Model in Remote Experimentation

The mediation model is basically composed of 5 categories focused on the acquisition of a better understanding of scientific concepts by the students and on providing a greater ease in the evaluation of the teaching and learning process by the teacher.

The Model categories are: Stage 1 (Pre-Test), Stage 2 (Conceptualization), Stage 3 (Post-Test 1), Stage 4 (Remote Experimentation) and Stage 5 (Post-Test 2), as shown in Fig. 2.

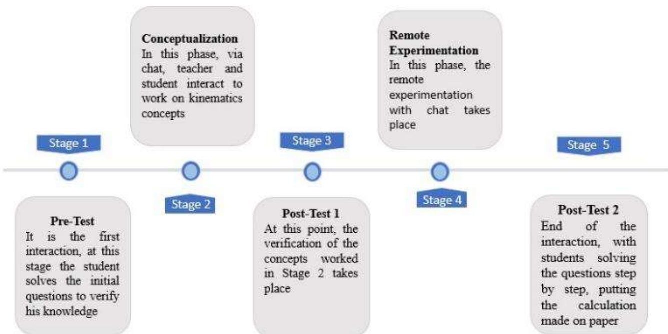


Fig. 2. Mediation Model

Students were evaluated in a unique way, as each student has their own Zone of Proximal Development. The students received questionnaires on Kinematics topics in order to identify the questions they were able to solve for themselves and the problems that referred them to the ZPD. During the process, the questionnaires applied to the students could be different, as they depended on the difficulties presented by the student and observed by the teacher.

When registered in the system, students received a login and password to access the Physics laboratory course. On the initial entry screen, the student found reading material, explanatory videos and simulators, before solving the Pre-Test.

Stage 1 – The student accesses the Learning Environment, using a login and password, answers the Kinematics questionnaire (Pre-Test) and sends the answers to the teacher. From the answers received, the teacher notes the successes, errors and conceptual confusions in a form that contains all the resolved questions, with developments and justifications. A sheet attached to the test tracks the student's development.

TABLE I presents an excerpt from one of the Pre-Tests applied to illustrate the procedure. It contains the question, the level at which the student is (ADL, ZPD or LPD), date of the activity (record of the day) for teacher control, as the process consists of a sequence of interactions. Next to each resolved question, the errors answers or correct (0 or 1) are indicated.

Upon receiving the answers sent by the student, the teacher checked, mainly, the subjective answers, because, in this case, he evaluated the approximation or not of the correct answer. With the subsequent recording of the student's level in TABLE 1. For correct answer, AVD, next ZPD answer and LPD incorrect answer.

TABLE I. Student's individual follow-up form by interaction

Question	Student Development Levels			
	Actual Development Level (ADL)	***Proximal Development Zone (ZPD)***	***Potential Development Level (LPD)***	***Record of the day***
Question 1			X	
Question 2			X	
Question 3		X		10/10
Question 4	X			
Question 5			X	

Question	Kinematic Concepts	
Question 1	The physical term "time" can be understood as: a. Acceleration of an object b. The movement performed by the mobile c. The speed of a vehicle d. Temperature (χ) e. The duration of a phenomenon	0
Question 2	A cyclist cycles through a section of the city from the moment equal to 16h until 16h15min. Can it be said that the time interval he cycled was 15 minutes? a. ( ) True b. (χ) False	0
Question 3	A bird takes off at 6h am and stops at 6h30min. How long did the bird fly? 6h30min - 6h = 30min	1
Question 4	The mathematical expression used to calculate the speed is: a. $\Delta s/\Delta v$ b. $\Delta x/\Delta v$ c. $\Delta s/\Delta t$ (χ) d. $\Delta t/\Delta s$ e. $\Delta t/\Delta v$	1
Question 5	A particle walks from km10 to km15. It starts this path at a time equal to 1h and ends at a time equal to 2h. By how much was the velocity developed by the particle? a. 5km/h b. 10kilometers/hour c. 15km/h d. 2km/h e. 1/2km/h (χ)	0
Student: Y______________		

Therefore, it was the teacher's responsibility to analyze and recognize the issues of difficulties for the student and outline a differentiated strategy to be executed. This form identifies the ADL, ZPD and LPD.

Stage 2 – Identified the Kinematics topics in which the student found difficulty, the teacher's strategy was executed on the determined items. At this moment, the interaction between student, content and teacher took place via chat in the remote experimentation environment. By completing and analyzing the form, the teacher became aware of the student's ZPD and knew exactly the concepts he should emphasize in the study.

Stage 3 – After studying the concepts, the student solved Post-Test 1, composed of questions to verify understanding. The mapping via the conceptual understanding form was redone and the student's progress was checked. Thus, depending on the result, the student could develop remote experimentation or continue their studies.

Stage 4 – With the new mapping, the teacher obtained updated ADL and ZPD science. A video is previously presented explaining the purpose of the experimental practice. Phase in which remote experimentation took place and persistent doubts were worked out. Fig. 3, in Portuguese, illustrates the webcam that films and records the execution of the experiment, shows the proposed questions, as well as the chat between the student and the teacher. From the experimental execution, data were collected by the student and support was provided by the teacher who mediated the study via chat.

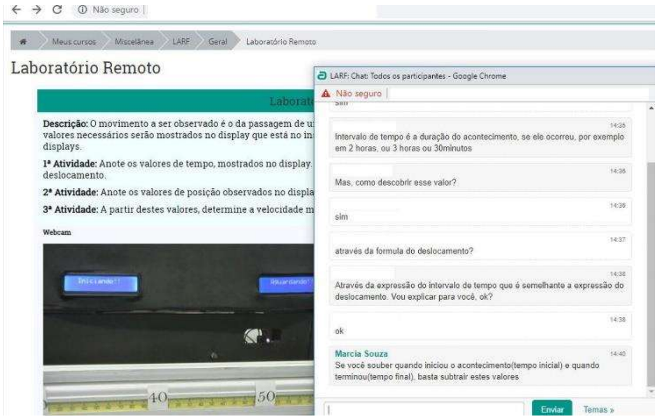


Fig.3 Shows the apparatus of the experiment and the teacher solving doubts (in Portuguese)

Stage 5 – At this moment, the student thoroughly develops the questions proposed in Post-Test 2, with his own hand, using pencil and paper. Mediation ends after the emphasized content.

C. Pre-Test and Post-Test applied to students

Testing and data collection took place at a Manaus public school. The number of 17 students regularly enrolled in the 1st year of high school in the night shift participated in the test. From the collection of user profile data, it was observed that most participants, 71% were over 18 years old, 23% were between 16 and 17 years old and 6% were aged between 15 and 16 years old. Of the total, 65% were male and 35% were female. After presenting the objective of the project, the students were registered in the system and received a login and password to access the content.

In the first access to LARF, the student answered the Pre-Test, illustrated in TABLE I of Section B, with ten questions about the physical concepts of Kinematics. Based on the answers provided by the students, the lesson plan was executed with the application of the Mediation Model in Remote Experimentation, following all the stages. After the Remote Experimentation, the students were evaluated with the Post-Test 1 on kinematic concepts, to verify the understanding of the concepts, shown in TABLE II.

TABLE II. Student's individual follow-up form by interaction Post-Test 1

Question	Kinematic Concepts (Post-Test 1)	
Question1	One hour equals how many minutes? a. 60min: b. 50min c. 20min d. 30min e. 40min	1
Question2	How do you write the abbreviated time unit? ---	1
Question3	The duration of a phenomenon is 2.5 h. Convert this time to hours and minutes. ---	1
Question4	(UFSM) The average speed of an athlete who runs 100m in 10s is, in km/h: a. 36 b. 24 c. 3 d. 30 e. 18	1
Question5	A truck travels 500 km in 7 hours. How much speed did he develop? ---	1
Question6	A car travels at a speed of 20 m/s in 10 s. What is the displacement of the car in meters? ---	1
Question7	The average speed of a particle that runs 200m in 20s is, in km/h?	1
Question8	How can we determine the speed of a mobile? a. Multiplying displacement by time b. Multiplying the acceleration by the time c. Dividing displacement by time d. Dividing acceleration by time e. Dividing time by displacement	1
Question9	A vehicle has a speed of 36 km/h in 10 s. The displacement made by the car is 100m a. True b. False	1
Question10	The physical term "time" can be understood as a. Temperature b. Displacement carried out by the mobile c. Vehicle speed d. Duration of an event e. Acceleration of an object	1
Student: Y______________		

The questions were corrected and the evaluation was carried out to verify the student's change of stage. Once considered suitable, the student moves on to the final stage with the application of Post-Test 2. Being solved individually by the student with his own hand, illustrated in Fig. 4. Post-Test 2 was carried out in an experimental space, with the execution of the experiment, observation, data collection by experimental space, with the execution of the experiment, observation, data collection by the student and detailed calculations on paper.

Fig. 4. Post-Test 2 on kinematic concepts

At the end of the execution of the Mediation Model, a quantitative study was carried out on the individual results of the students, in all tests. A graph was set up to observe the evolution of students' understanding, illustrated in Fig. 5.

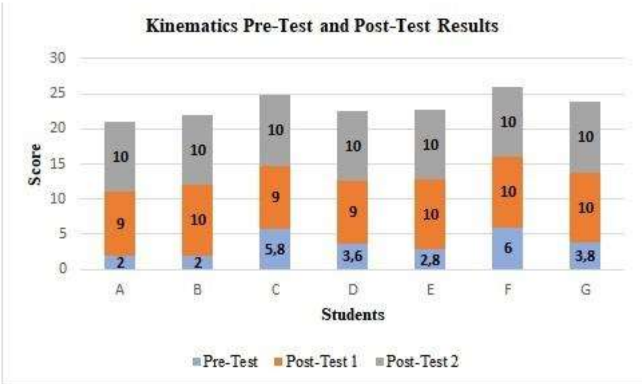


Fig. 5. Pre-Test and Post-Test 2 Results

It is possible to observe from the graph that the grades increased, as the conceptual interactions and remote experimentation took place. |Thus, at the end of the mediation process, both the scores and the students' testimonies point to signs of conceptual compression.

D. Student Opinion Survey

An opinion poll was carried out with the students via a questionnaire. The questionnaire was about the Usability of the LARF System and Physical Science, it had the purpose of verifying the applicability of the Mediation Model in Remote Experimentation, shown in TABLE III.

TABLE III. Questionnaire about the usability of the LARF

Question	Usability of the LARF system
Question 1	Do you like to study Physics?
Question 2	Do you believe that studying Physics is important?
Question 3	Is Physics present in your daily life?
Question 4	Do you think that the Remote Access Laboratory for educational purposes can encourage and collaborate for the understanding of important concepts of Physics?
Question 5	Do you usually or used to do Physics practices at school or at home?

Question 6	Which factor do you consider to be most important for understanding the concepts of Physics through the use of LARF?
Question 7	Do you think using Remote Access Labs makes Physics classes interesting?
Question 8	Do classes with Remote Access Laboratories encourage students to learn about Physics concepts?
Question 9	Do you believe that experiments through the Remote Access Laboratory help to understand the concepts of Physics?
Question 10	Do you think that classes with experimental practices improve your understanding of Physics concepts?
Question 11	Did you access LARF during the week or weekend? Morning, afternoon or night?
Question 12	Would you like to study physics at LARF?
Question 13	What other Physics experiment would you like to do via LARF?
Question 14	Has your participation in LARF changed your thinking about Physics?
Question 15	How did you access the Physics Laboratory?
Question 16	What did you think of the experience with LARF?
Question 17	Do you have any suggestions for improving this teaching approach?

To evaluate the result of the opinion poll, a variation of the Technology Acceptance Model (TAM) was used. Based on the research by Davis (1989), in the evaluation of the results, the construct Perceived Usefulness (UP) in LARF was analyzed.

In [12] new scales were developed and validated for two particular variables, which are perceived ease of use and perceived usefulness, which are assumed to be essential determinants of user acceptance.

UP was used in the research in order to assess the acceptance or rejection of the Mediation Model in Remote Experimentation by the students participating in the research, shown in TABLE IV.

TABLE IV. Illustrates the issues for perceived usefulness

Question	Perceived Usefulness in LARF	
Question 1	Do you like to study Physics?	[UP1]
Question 2	Do you believe that studying Physics is important?	[UP2]
Question 3	Is Physics present in your daily life?	[UP3]
Question 4	Do you think using Remote Access Labs makes Physics classes interesting?	[UP4]
Question 5	Do you think that classes with experimental practices improve your understanding of Physics concepts?	[UP5]
Question 6	Do classes with Remote Access Laboratories encourage students to learn Physics concepts?	[UP6]
Question 7	Do you believe that experiments through the Remote Access Laboratory help to understand the concepts of Physics?	[UP7]

Based on the students' answers, it was possible to assess the belief in the usefulness of the tool for teaching and learning Physics. The questions classified as UP used a Likert Scale, with alternatives: “I totally disagree”, “I disagree”, “Indifferent”, “I agree”, “I totally agree”.’

PSPP is a tool used for statistical examination of sampled data. The PSPP tool was used to determine Cronbach's Alpha for UP in the assessment of the reliability of the questions. Cronbach's Alpha for UP was 0.73, which represents a considerable value of internal reliability for the mediation instrument. The questions that make up the instrument were answered by the students. In TABLE V, the valid answers, the mean of the values, the standard deviation, the maximum and minimum values for each question are presented.

TABLE V. UP statistics

Question	UP1	UP2	UP3	UP4	UP5	UP5	UP7
Valid	17	17	17	17	17	17	17
Missing	0	0	0	0	0	0	0
Average	3.82	4.29	4.06	4.82	4.53	4.41	4.47
Std Dev	0.88	0.77	0.66	0.39	0.51	0.62	0.51
Minimum	2	2	3	4	4	3	4
Maximum	5	5	5	5	5	5	5

A study was carried out quantifying the students' answers to the questions about LARF and Physical Sciences, to verify the acceptance or rejection of the proposed Mediation Model. So, for Question 1: Do you like to study Physics? 59% (10 students) agreed that they like to study Physics, 17% (3 students) strongly agreed that they like to study Physics and 12% (2 students) said that they do not like to study Physics and 12% (2 students) strongly disagree that they like Physics the answers shown in Fig. 6.

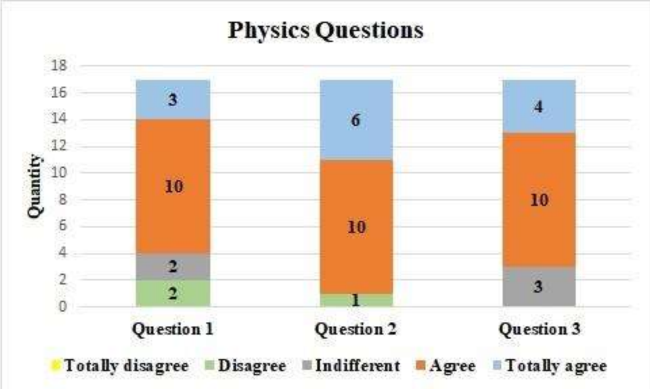


Fig. 6. Answers to Physics Questions

Question 2: Do you believe that studying Physics is important? Of the total, 59% (10 students) believe that the study of Physics is important, 35% (6 students) completely agree that the study of Physics is important and 6% (1 student disagrees that studying Physical Science is important, illustrated in Fig. 6.

Question 3: Is Physics present in your daily life? Overall, 59% (10 students) agreed, 23% (4 students) completely agreed and 18% (3 participants) are indifferent to the existence of the relationship between Physics and their daily lives, shown in Fig. 6.

Question 4: Do you think that the Remote Access Laboratory for educational purposes can encourage and collaborate for the understanding of important concepts of Physics? Fig. 7 shows the students' agreement on the encouragement and collaboration of the LARF tool for the understanding of physical concepts. Of the total, 35% (6 students) agree and 65% (11 students) completely agree.

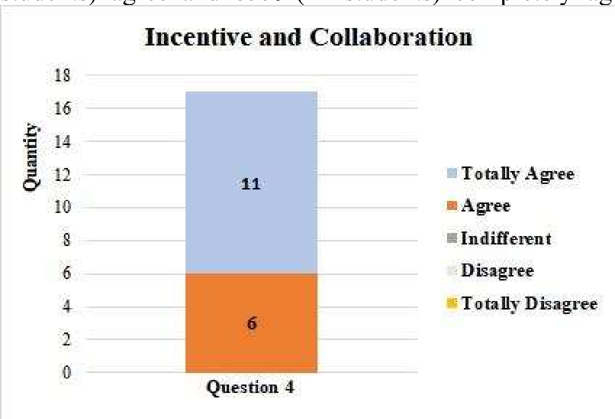
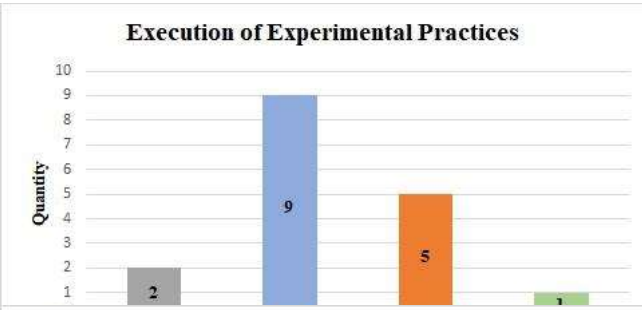
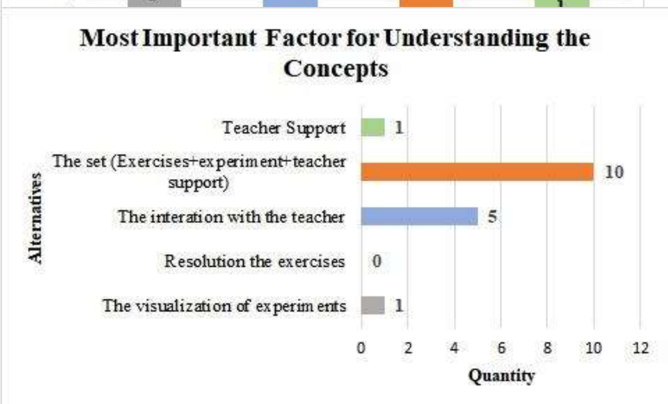


Fig. 7. Answers about encouragement and collaboration

For Question 5: Do you usually or used to do Physics practices at school or at home? It is possible to observe that most students do not usually carry out experimental practices, illustrated in Fig. 8. Of the total, 6% (1 student) say they always carry out experiments, 12% (2 students) say they always carry out experiments, 29% (5 students) say they do it sometimes and 53% (9 students) do not perform experimental practices.





Question 6: Which factor do you consider to be most important for understanding the concepts of Physics through the use of LARF? By observation, 6% (1 student), say that understanding occurs only with the visualization of the experiment and 29% (5 students), believe that interaction with the teacher is essential for understanding the concepts. However, 59% (10 students) declare that the set (exercises + experiment + mediation) is the most important factor in understanding the concepts, shown in Fig. 9.

Fig. 9. Express the most important factor for understanding

For Question 7: Do you think using Remote Access Labs makes Physics classes interesting? Fig. 10 expresses that 18% (3 students) agree that LARF makes Physics classes interesting and 82% (14 students) totally agree.

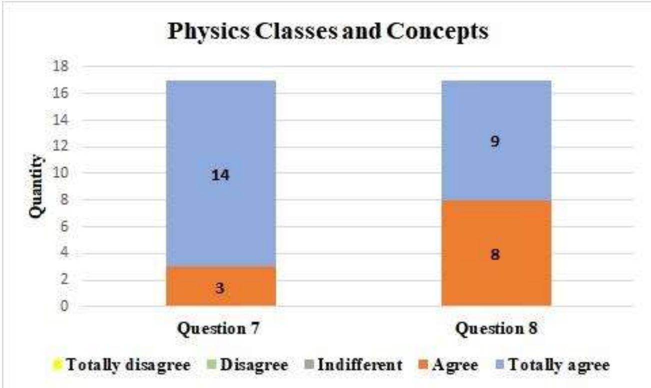


Fig. 10. Answer about LARF Physics interesting

Question 8: Do classes with Remote Access Laboratories encourage students to learn about Physics concepts? For this issue, Fig. 10, shows that 47% (8 students) agree and 53% (9 students) totally agree.

For Question 9: Do you believe that experiments through the Remote Access Laboratory help to understand the concepts of Physics? Of the total, 47% (8 students) completely agree and 53% (9 students) agree that LARF helps in understanding the concepts of Physics, illustrated in Fig. 11.

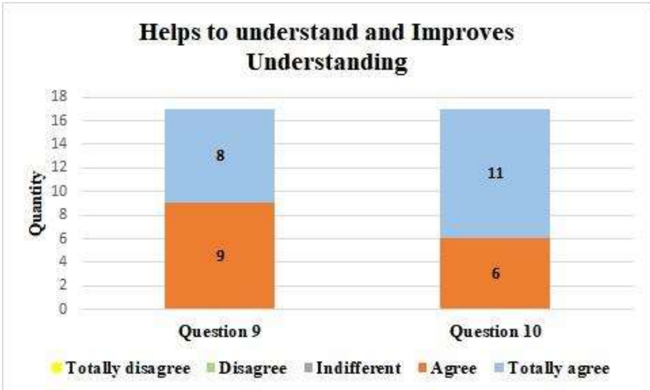


Fig. 11. About LARF to helps understanding

About Question 10: Do you think that classes with experimental practices improve your understanding of Physics concepts? Of the total, 35% (6 students) agreed and 65% (11 students) agreed that experimental classes help in understanding the concepts, illustrated in Fig. 12.

Question 11: Did you access LARF during the week or weekend? Morning, afternoon or night? Most students 82% (14 students) accessed it at night, 12% (2 students) accessed it in the afternoon and 6% (1 student) accessed it in the morning.

For Question 12: Would you like to study physics at LARF? In total, 94% (16 students) said they would like to and 6% (1 student) remained indifferent to the study of

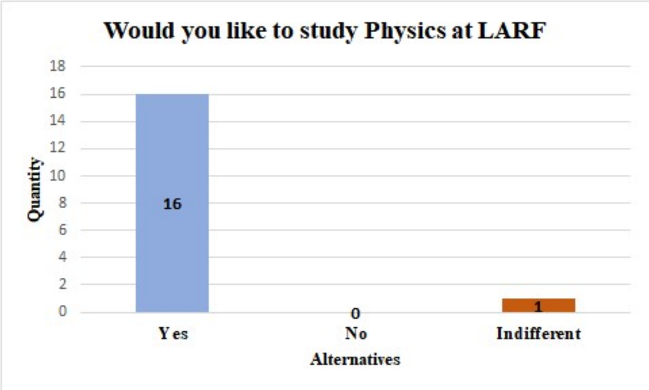


Fig. 12. Questioning about the desire to study in LARF

Question 13: What other Physics experiment would you like to do via LARF? Strength, Density, Mechanics 2, all subjects. The content that repeated the most was Strength.

Questions 14 and 16, as they are open questions, were analyzed using the Analysis Grid, with the application of Bardin's Content Analysis criteria [13], thus undergoing categorization. Question 13, even though it was open, was not categorized, as the student only opined about the content he would like to study. Question 14: Has your participation in LARF changed your thinking about Physics? The answers to this question were positive, shown in TABLE VI.

TABLE VI. Categories generated to change thinking about Physics

<table>
<tr><th rowspan="3">Students</th><th rowspan="3">Opinions</th><th colspan="4">Categories</th></tr>
<tr><th rowspan="2">change of mind</th><th colspan="3">knowledge</th></tr>
<tr><th>helped</th><th>took doubts</th><th>I learned</th></tr>
<tr><td>A</td><td>“Yes, they could have more classes like this!”</td><td>X</td><td colspan="3"></td></tr>
<tr><td>B</td><td>“Yes, because it helped me a lot”.”.</td><td>X</td><td colspan="3">X</td></tr>
<tr><td>C</td><td>“Yes i learned a lot ”.</td><td>X</td><td colspan="3"></td></tr>
<tr><td>D</td><td>“Yes, because I had neer seen an experience on the internet. And clearing doubts with the teacher.”</td><td>X</td><td colspan="3">X</td></tr>
<tr><td>E</td><td>“Yes completely ”.</td><td>X</td><td colspan="3"></td></tr>
<tr><td>F</td><td>“Yes”.</td><td>X</td><td colspan="3">X</td></tr>
<tr><td colspan="2">TOTAL</td><td>17</td><td colspan="3">3</td></tr>
</table>

Of the 17 participating students, 100% of the students considered that the experience with the Mediation Model at LARF changed their thinking about Physics, only six responses were inserted due to repetition of expressions. In Thought and Language, [14] states that the meaning of a word reflects such a close fusion between thought and language that it is not easy to report whether it is a phenomenon of thought or of language.

The change of thinking expressed by the students can be seen in the column of the category change of thinking, the answers were analyzed, through the close relationship between thought and language considered by [14].

In the Learning category, 17.7% (3 students) spontaneously included terms that point to the idea of understanding, “helped”, “took doubts” and “I lerned”. Student claims can be compared with Pre-Test and Post-Test results.

Question 15: How did you access the Physics Laboratory? In its entirety, 100% (17 students) accessed the course through the notebook. Question 15 was not categorized, as the students only mentioned how to access LARF.

Question 16: What did you think of the experience with LARF? It was an open question that allowed the expression of opinions, the answers is illustrated in TABLE VII.

TABLE VII. Shows the categorization for the sixteenth question

<table>
<tr><th rowspan="2"></th><th rowspan="2">Opinions</th><th colspan="2">Understanding</th></tr>
<tr><th>Nice</th><th>knowledge</th></tr>
<tr><td>A</td><td>“Great, completely effective classes."</td><td>X</td><td>X</td></tr>
<tr><td>B</td><td>“It was very important for me to learn a little”.</td><td>X</td><td>X</td></tr>
<tr><td>C</td><td>“It's good, excellent, for those who like to study physics I liked it a lot, it improves performance in the classroom”.</td><td>X</td><td>X</td></tr>
<tr><td>D</td><td>“Very good with the classes to easily learn about physics”.</td><td>X</td><td>X</td></tr>
<tr><td>E</td><td>“Very good.</td><td>X</td><td></td></tr>
<tr><td>F</td><td>"Excellent!"</td><td>X</td><td></td></tr>
<tr><td>G</td><td>“Very good”.</td><td>X</td><td></td></tr>
<tr><td>H</td><td>"Very good, it was an incredible experience and I will take this teaching for the rest of my life".</td><td>X</td><td></td></tr>
<tr><td>I</td><td>"I really liked it"</td><td>X</td><td></td></tr>
<tr><td>J</td><td>"Very important for students to develop a lot with the teachers".</td><td>X</td><td>X</td></tr>
<tr><td>L</td><td>“Very important for development and knowledge”.</td><td>X</td><td></td></tr>
<tr><td>M</td><td>“Very interesting”.</td><td>X</td><td></td></tr>
<tr><td>N</td><td>"This study mechanism was very cool, interesting. I like it a lot".</td><td>X</td><td></td></tr>
<tr><td>O</td><td>"I thought it was really cool, the physics became better, I understood it better and I saw that it was much easier to learn."</td><td>X</td><td>X</td></tr>
<tr><td>P</td><td>“Nice”.</td><td>X</td><td></td></tr>
<tr><td>Q</td><td>“Nice”.</td><td>X</td><td></td></tr>
<tr><td>R</td><td>“Nice”.</td><td>X</td><td></td></tr>
<tr><td colspan="2">TOTAL</td><td>17</td><td>6</td></tr>
</table>

In total, 100% of the students reported that the experience was Nice (“great”, “good”, “like it”), which brings us back to Vygotsky’s thoughts in The Social Formation of the Mind regarding the role of toys. for child development.

According to [14], there are interesting games for the child if they provide pleasure, but there are games in which the activity itself is not pleasant. Sports games are often followed by discontent when the score is unfavorable to the child. In this way, the fact that the student considers the experience pleasant can be understood by meeting the needs.

For the Knowledge category, 36% (6 students) reported having learned the theory and the resurgence of the Knowledge category reinforced the observation made in Question 14.

For Question 17: Do you have any suggestions for improving this teaching approach? The answers provided were: “I didn't look that it was very good and necessary”.

“more classes in the week”.

“no”.

Of the 17 students, 5.9% (1 student) expressed that they should have more weekly classes, 29.4% (5 students) answered “no” and the remaining 64.7% (11 students) did not comment, therefore, the question was not categorized. The absence of opinions could be linked to the lack of technological knowledge to give an opinion.

IV. Evaluation Results

With the answers obtained in the Pre-Test, the students' difficulties were mapped and the ADL, LPD and ZPD levels were identified, allowing the elaboration of a unique teaching-learning strategy by the teacher and the application of the Mediation Model in Remote Experimentation.

From the results of the Pre-Test and Post-Tests, it was possible to observe an evolution of the conceptual understanding of Kinematics by the students, as they were able to answer objective and subjective questions, arising from remote experimentation, showing their power of concentration, observation and analysis.

The study on the usability of the tool with the Mediation Model in Remote Experimentation, made it possible to visualize the acceptance of the Technology, as well as the Mediation Model. Comparing the test results, the evaluation of the tool with the application of the Mediation Model and the analysis of students' opinions through open questions, a positive and promising result was obtained for the extension of the Mediation Model in Remote Experimentation to other disciplines, areas or levels of education.

V. Conclusion

The research showed a proposal of a mediation model for remote experimentation based on the Zone of Proximal Development and mediation. The work presented the effectiveness of the mediation model in remote experimentation on kinematic concepts, in the discipline of Physics of High School, through evaluations with students. The Learning Environment (Moodle) was used for the administration of pedagogical materials, emphasizing the chat linked to remote experimentation that integrates the LARF system. The approach was developed in order to enable the execution of the Mediation Model in Remote Experimentation.

The Remote Access Laboratories generally do not cover student interaction strategies, content, experimentation and teacher, causing the problem addressed in the research.

For the validation of the proposal, evaluations were carried out in a school environment with volunteer students. The students' performance evidenced the efficiency of the approach, as it showed the evolution in the understanding of concepts, in the ability to solve questions and in the change of vision in relation to Physics.

In general, students appreciated the model of mediation in remote experimentation, some commented that it was a remarkable, effective and excellent experience. Others were surprised to understand the concepts remotely and others requested re-enrollment to participate in new approaches.

As scientific contributions of the research, the following can be mentioned: the mediation model for remote experimentation, application of the theory of the Zone of Proximal Development to map the advances and difficulties of students. The individualized mapping, aiming at the orientation of the mediation model and the reinforcement for students and teachers in remote experimentation.

As limitations, the research had a small number of participating students and the questions determined and used for the application of the TAM.

As future work, we intend to deepen the TAM model, provide experimental automation reducing human intervention, promote an increase in experiments, introduce auxiliary agents for measurements, introduce other disciplines and promote improvements in evaluations.

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References

[1] H. Siswoyo Jo, and R. Siswoyo Jo, "Design and Development of Remote Laboratory System to Facilitate Online Learning in Hardware Programming Subjects", in 2020 13th International UNIMAS Engineering Conference (EnCon), out. 2020, p. 1–5. doi: 10.1109/EnCon51501.2020.9299326.

[2] P. Orduña, L.Rodríguez-Gil, I. Ângulo, G. Martinez, A. Villar, U. Hernández, P. Buitrago, R. Camacho, P. Marmolejo, and J. Garcia-Zúbia, "Addressing technical and organizational pitfalls of using remote laboratories in a commercial environment", in 2018 IEEE Frontiers in Education Conference (FIE), out. 2018, p. 1–7. doi: 10.1109/FIE.2018.8658903.

[3] A. Nafalski, M. Milosz, H. Considine, and Z. Nedić, "Overseas Use of the Remote Laboratory NetLab", in 2020 IEEE Global Engineering Education Conference (EDUCON), abr. 2020, p. 568–573. doi: 10.1109/EDUCON45650.2020.9125230.

[4] R. Costa, F. Pérola, e C. Felgueiras, "μLAB A remote laboratory to teach and learn the ATmega328p μC", in 2020 IEEE Global Engineering Education Conference (EDUCON), abr. 2020, p. 12–13. doi: 10.1109/EDUCON45650.2020.9125336.

[5] T. Klinger, C. Kreiter, A. Pester, and C. Madritsch, "Building a Remote Laboratory for Advanced Experiments in Transmission Line Theory", in 2019 IEEE Global Engineering Education Conference (EDUCON), abr. 2019, p. 718–721. doi: 10.1109/EDUCON.2019.8725189.

[6] M. d. S. Xavier, J. F. d. M. Netto, T. O. Almeida and J. M. de Carvalho, "A Proposal of a Remote Laboratory for Pedagogical Mediation in Kinematics Experiments," 2019 IEEE Frontiers in Education Conference (FIE), 2019, pp. 1-7, doi: 10.1109/FIE43999.2019.9028590.

[7] P. Vitliemov, D. Bratanov, e M. Marinov, "An Approach to Use Virtual and Remote Labs in Mechatronics Education Based on Cloud Services", in 2020 7th International Conference on Energy Efficiency and Agricultural Engineering (EE AE), nov. 2020, p. 1–4. doi: 10.1109/EEAE49144.2020.9279072.

[8] S. B. Merriam, Qualitative research: a guide to design and implementation. San Francisco: Jossey-Bass, 2009.

[9] R.Bogdan, and S.K.Biklen. Qualitative Research for education. Boston, MA:Allyn & Bacon, 1997.

[10] J. V. Wertsch, Vygotsky and the social formation of mind. Cambridge, Mass.: Harvard University Press, 1985.

[11] N. Guerrero, H. Carmen, Applications of Vygotskyan Concept of Mediatioin SLA Colombian Applied Linguistics Journal, n. 9, p. 213-228, 2007.

[12] F. D. Davis, "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology". Published by Management Information Systems of Minnesota, 1989.

[13] Bardin, L, Content analysis. São Paulo: Edições, 2011; 70(279), 978-8562938047.

[14] L. Vygotsky. Thought and Language. Publisher: Cambridge, Mass:MIT Press, 1962.