# DEVELOPMENT OF EXPERIMENTAL SKILLS IN PHYSICS STUDENTS OF C.E.T.I. - MÔNICA VALE FULL-TIME TEACHING CENTER, APPLIED TO THERMAL PHENOMENA

**Ubiraci Silva Nascimento[1], Fernando Lima de Oliveira[2], Marcio da Silva Tavares[3], Edvan Moreira[4], Anderson Costa da Silva[5], José de Ribamar Pestana Filho[6], Valter Valder Reis Beckman[7] and Willian de Vasconcelos Silva[8]**

[1]Dr.in Mechanical Engineering - UNICAMP
São Luís, Maranhão - Brazil
[2]Dr.in Mechanical Engineering - ITA
São Luís, Maranhão - Brazil
[3]Dr.in Physics - IFMA/UEMA
São Luís, Maranhão - Brazil
[4]Dr.in Physics - UFC
São Luís, Maranhão - Brazil
[5]Dr.in Physics - PUCG
São Luís, Maranhão - Brazil
[6]Master in Educational Science - IPLAC/UEMA
São Luís, Maranhão - Brazil
[7]Specialist in Physics - UFMA/UEMA
São Luís, Maranhão - Brazil
[8] Master's Degree in Mechanical Engineering - UNICAMP
São Paulo, Campinas - Brazil

**ABSTRACT**
Thermal effects can be described in both simple and more complex situations, making use of variables such as: temperature, pressure and volume. One of the applications of thermodynamics is linked to materials science, which studies means to obtain new types of materials, which have well-defined physical properties, as is the case in engineering, where the manufacturing processes of new materials involve a lot of heat transfer in obtaining new raw materials. Based on this knowledge, our project was developed in a systemic way, through proposed activities, which provided the discovery, approximation and integration with nature through physics, providing not only students and teachers, but any man to recognize himself in the world, with the world and acting on it in a sustainable way. The student saw himself as the subject of his own knowledge, he appropriated it through the connection he makes between the theoretical and practical knowledge offered by human culture that relates him to the action of his own existence. The experimental activities were applied in the pedagogical didactic context, contributing to the teaching of science in general. In particular, the Physics teachers revealed a greater concern with the use of this methodology because the students, for the most part, did not like the discipline, but started to like it from the participation in the realization of the experiments. As a result of the project, the use of the systemic model provided a motivational stimulus, which was one of the pillars of the improvement of the teaching-learning process. After the application of the project, we carried out a diagnosis with the students of the C.E.T.I - Mônica Vale school, where it was noticed that many students became interested in the area of Physics and with a very advanced knowledge, since they had full-time experimental and theoretical classes.

**Keywords:** Learning, Experimental Activity, Thermal Effects.

## INTRODUCTION

It has been observed that physics classes in the state high school system of São Luís do Maranhão are almost always not accompanied by experimental practical classes. Thus, this project was applied to fill this gap and contribute to an interdisciplinary, dialectical and meaningful teaching.

The disciplines that fall within the natural sciences, as well as physics, require adequate guidance from the teacher and he has to transform this reality, seeking the need for the interrelationship of theory with practice (praxis). All efforts must be added to achieve transformations that raise the quality of the teaching-learning process, efforts that allow us to accumulate experiences and define methodological thinking with its own and original characteristics, in correspondence with the need to train physics students and teachers with a broad profile capable of giving answers to the problems that arise in the daily life of our social reality and future problems that may arise.

One of the main branches of Physics and Engineering is Thermodynamics, the study of the laws that govern the relationship between heat, work and other forms of energy. One of the main concepts in the study of thermodynamics is Temperature, where it is one of the seven fundamental quantities in the SI. Scientists measure temperature on the Kelvin scale,

whose unit is kelvin K, although there is no upper limit to the temperature of a body, there is a lower limit, where the limit temperature is taken to be the zero on the Kelvin scale of temperature. By definition, the triple point temperature of water (the state in which the solid, liquid, and gaseous phases coexist in equilibrium) is 273.16 K. Other temperatures are defined from measurements performed with a constant-volume gas thermometer, in which a gas sample is held at a constant volume so that the gas pressure is proportional to the temperature. The temperature T measured by a gas thermometer is defined by the equation:

$$T = (273{,}16k)\left(\lim_{n\to 1}\frac{p}{p_3}\right)$$

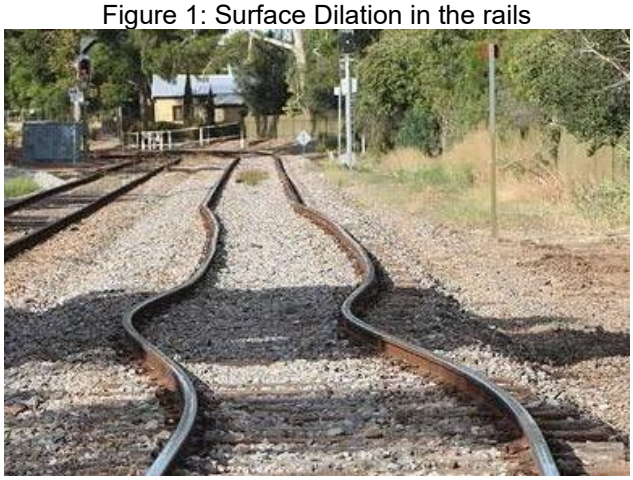
The properties of many bodies change considerably when they are subjected to a temperature variation, such as: when the temperature increases, the volume of a liquid increases; a metal bar is a little longer; The electrical resistance of a wire increases and so does the pressure of a confined gas. Any of these changes can be used as the basis of an instrument that helps us understand the concept of temperature. When a thermometer and another object are brought into contact, they reach, after some time, thermal equilibrium. After thermal equilibrium is reached, the thermometer reading is considered to be the temperature of the other object. The process is coherent because of the zero law of thermodynamics: If two bodies A and B are in thermal equilibrium with a third body C, bodies A and B are in thermal equilibrium with each other. This law constitutes the basis for temperature measurement, where whenever a body has temperature equality with the thermometer, we can say that the body has the temperature read on the thermometer (ÇENGEL.2012).

In Thermodynamics, Thermal Dilation is the phenomenon that occurs to the increase in the volume of a body caused by the increase in its temperature. The dilation of the bodies will not be the same for different materials, as each one has a characteristic coefficient of expansion. Temperature measures the degree of agitation of molecules, a higher degree of agitation indicates a higher temperature. Thus, when we heat a body, the degree of agitation of the molecules that constitute it consequently increases. This event causes an increase in the dimensions of the body. The decrease in temperature consequently causes a shrinkage in the dimensions of the body, called thermal contraction. In solids, the increase or decrease in temperature causes changes in linear dimensions, as well as in surface and volumetric dimensions.

Linear Expansion of Solids occurs when the body has expansion in one dimension, such as telephone or light wires that are exposed to the sun on hot summer days vary their

temperatures considerably, causing the wire to extend causing a greater bending, as it increases its length from an initial length L_i to a final length L_f. Surface Expansion of Solids occurs with increasing volume of a body that comprises two dimensions (length and width, which generates the area). This process results from the body's exposure to heat, causing the atoms to agitate, increasing the distance between them, that is, dilating. The Volumetric Expansion of Solids occurs in the three dimensions of a body (height, length and width) that has any initial volume.

Figure 1: Surface Dilation in the rails



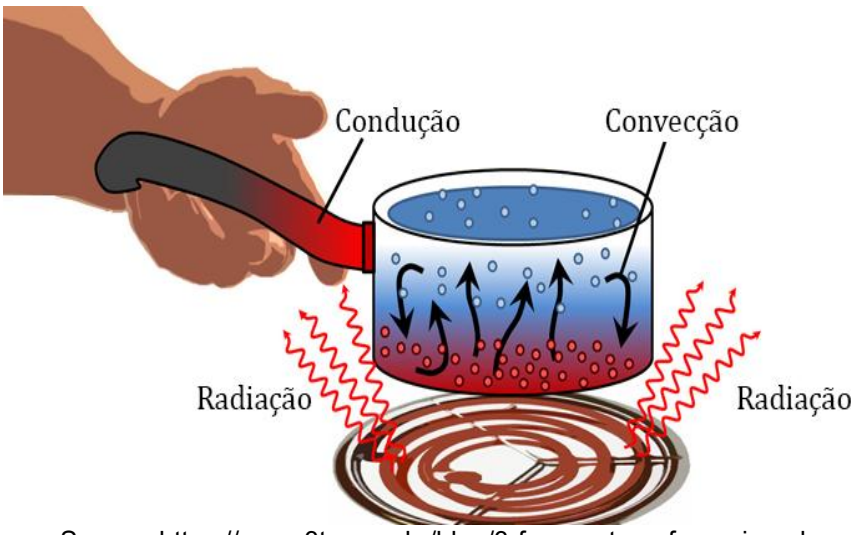
Source: https://www.coladaweb.com/wp-content/uploads/2014/12/dilatacao.jpg

Q heat is the energy transferred from a system to the environment or from the environment to a system because of a temperature difference. Heat is measured in joules (J), calories (cal), or British thermal units (Btu); Among these units, there are the following relationships:

$$1cal \ = \ 3,968 \ x \ 10^{-3} Btu \ = \ 4,1868J$$

For heat exchange to occur, it is necessary that it be transferred from one region to another through the body itself, or from one body to another. There are three heat transfer processes studied in thermology, they are: conduction, convection and radiation. Radiation is the propagation of electromagnetic waves that do not need a medium to propagate, while conduction and convection are transfer processes that require a material medium to propagate. Conduction consists of the propagation of heat inside an irregularly heated solid body or between different solid bodies in direct contact. Convection, on the other hand, is a process that consists of moving parts of the fluid within the fluid itself. This type of energy transfer happens when a fluid, such as air or water, comes into contact with an object whose temperature is higher than that of the fluid.

Figure 2: Heat Transfer Processes




Source: https://www.3tc.com.br/blog/3-formas-transferencia-calor

The general objective of the project was, therefore, the elaboration of a systemic model that develops Experimental Skills in Physics Students of the 2nd year of High School at C.E.T.I Mônica Vale, located in the neighborhood of Vinhais in São Luís/MA.

The Mônica Vale Full-Time Teaching Center, a state public school, located at Rua 13, S/N, Conjunto Vinhais offers face-to-face high school in the state and public network. The school stands out for its accessibility, with handrails, wide doors and adequate bathrooms. Its facilities include a library, sports court, covered and uncovered patio, air-conditioned classrooms, science laboratory, kitchen and cafeteria with school meals. The school prioritizes technology, providing access to the internet, computers, tablets and a computer lab. It promotes sustainability with green areas and offers teaching materials, musical instruments, sound equipment, cultural, sports and pedagogical materials. It has a qualified team, including librarians, food safety professionals and pedagogical support.

The C. E. T. I. Maria Monica Vale has an excellent evaluation made by the 2023 School Census (4.4), which reflects the institution's preparation and concern with quality education. The evaluation, which can be seen below, is made by students, parents and school staff.

The project also covered the following specific objectives:

- Presentation of theoretical knowledge of the epistemological and psychopedagogical foundations in the formation of skills of the Physics teacher.
- Establishment of interdisciplinary and dialectical scripts of experimental skills.
- Diagnosis and encouragement of interest in theoretical and experimental research in teachers and students who develop work in the teaching of practical sciences.

- Evaluation of the development of skills in the elaboration of some experimental kits, models, from alternative materials, to show that it is possible to carry out some physics experiments, without the need for a conventional laboratory.

The project trained about 175 (one hundred and seventy-five) students from the State Education Network of C.E.T.I - Mônica Vale in a maximum period of 1 (one) year, taking place in 2 (two) morning classes, 2 (two) afternoon classes and 1 (one) evening class. The project foresaw a duration of 320 hours, with 160 hours available for planning and evaluation of the results and 160 hours for its execution in the school, in such a way that for each of the 5 classes, 8 topics were worked on in 4 hours of class in each class, being (01 theoretical, 01 virtual, 01 experimental and 01 for the elaboration of experimental kits).

Goals linked to the contents that were worked on:

- Bibliographic research.
- Preparation of Didactic Material.
- Thermometry;
- Thermal expansion of solids;
- Thermal expansion of liquids;
- Calorimetry;
- Changes of State;
- Heat propagation;
- Thermal expansion of liquids;
- Thermodynamics;
- Applying assessments.
- Dissemination of the activities developed.

**THEORETICAL FRAMEWORK**

At the end of the last century and the beginning of the present in England and the United States, practical work was closely linked to school science curricula (ALVAREZ, 1998; ANDRADE, 1995 and BAYOLO & RIVERO, 1997). In this sense, the importance of the practical work of teaching Physics has been universally recognized, considering it as a useful educational strategy for achieving the objectives related to this subject (FERNANDEZ, 1998).

In the last 40 years, the study of skills has been intensely addressed by Science, so the question arises: Do skills today constitute a social problem not solved by the sciences? The answer is obviously yes, if we base it, this aspect can be expanded and deepened not

only from a theoretical point of view but also from a practical point of view, the knowledge of man as a social being is limited and in current times the possibilities of technologies related to his activity are infinite, now we will see it from the social edge,  It is no secret to anyone that in today's world the trend of globalization and unipolarization, as well as neoliberal policies in the Third World do not allow the development of personality, on the other hand there is still a minority with a possibility, the vast majority lacks them. The question then arises: what have we accomplished in teaching related to the development of skills?

In Brazil, some studies have begun to appear regarding experimental activities in science teaching, as revealed by Reginaldo et al (2012). In his study, he presents a close relationship between the learning of science and experimentation. Ovigli & Bertucci (2009) portrays the importance of the natural sciences in the pedagogical context of experiments.

The emergence of the Psyches as a relatively new form of reflection in the course of phylogeny is produced in the close relationship with the objective external reality. And to the same extent that it is made more and more complete, it is necessary for organisms to develop forms of action that are more and more effective and perfect in their activity of adaptation to it. Therefore, the psychic reflex is linked to the need to know the objective world, its properties and relations, in order to act on it, and originates in those practical processes of interaction of the individual with the environment (HENANDEZ & QUESADA, 1998).

The success of the activities that the subject performs depends to a large extent on the form in which they are assimilated by him, whose expression of assimilation of the activity in the executing plane constitutes habits and skills.

In this sense, the theoretical contribution made by Dr. Carlos Alvarez de Zayas (1989) stands out, in which he considers that skill is an element of content, and expresses a didactic language as a system of actions and operations to achieve an objective.

Digital teaching materials such as virtual simulations have been increasingly produced and used. Although they should not replace real experiments, using them as a complementary pedagogical tool increases students' chances of learning, with the caveat that the "instructional" use of technology consists of underusing its potential for learning (SANTOS et.al, 2015).

The experimental skill of Physical Sciences is the construction, by the student, of the way of acting inherent to a certain activity, which allows him to seek or use concepts, properties, relationships, physical and mathematical procedures, employ work strategies, perform reasoning, judgments that are necessary to solve problems in these areas (REGINALDO et al, 2012).

## METHODOLOGY

### CHARACTERIZATION OF THE AREA OF ACTIVITY

The project was carried out at C.E.T.I - Mônica Vale, located in the Vinhais neighborhood in São Luís/MA with a duration of 01 year (12 months), from September 2018 to August 2019 and was aimed at students in the 2nd year of high school, as it is about approaches to thermology content and was developed in two stages: The first focused on the qualification of students with the explanation of theoretical classes, with the use of data show and exhibition of simulation videos, followed by the presentation of a script for experimental demonstration. The second stage of the project was aimed at the elaboration of experimental kits with alternative materials, with the objective of demonstrating that practical classes can be held without the use of conventional laboratories.

The school operates in its own building, containing water from the public network, electricity also from the public network, sewage network and periodic garbage collection, has a structure with: Board room, teachers' room, computer lab, kitchen, library, reading room, auditorium and covered patio, also having the following resources: Parabolic, 23 existing rooms, 3 TV equipment, 2 DVD players, 2 printers, 5 stereos, 3 multimedia projectors – data show, 34 computers at the school, 4 for administrative use, 30 for student use, 140 employees, internet and broadband access and offers school meals for students, offering the following teaching modalities: regular education, high school and EJA.

Figure 3 - Location of the C.E. T.I. school. Maria Mônica Vale, Vinhais neighborhood


Source: Google Maps.

### METHODOLOGICAL PROCEDURES

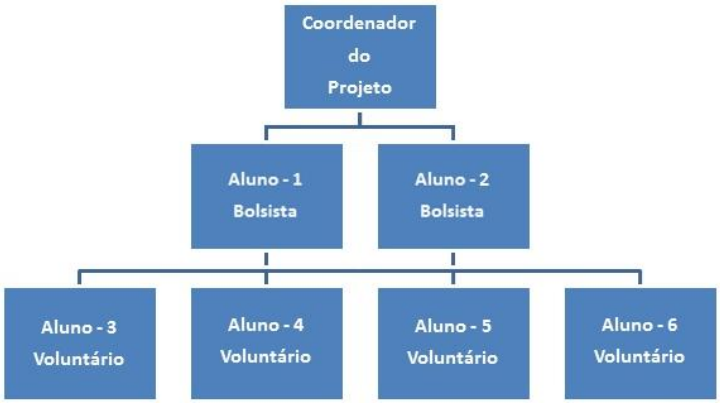
The project was carried out with a view to students in the 2nd year of high school because they are approaches to thermology contents. We focused on the qualification of students with the explanation of theoretical classes, followed by scripts for experimental

demonstration. For the development of the project, two students were selected, one with a scholarship and the other as a volunteer, both from the Physics and Mechanical Engineering courses, respectively. The project was developed in a systemic way, through proposed activities, where it can enable the discovery, approximation and integration with nature through physics, providing students and teachers. The project began in the second semester of 2018, where initially some bibliographic research was carried out regarding thermodynamics and how we could demonstrate the experiments in a clear and objective way of such content to students in the 2nd year of high school. It started with the experiments on Solid Dilation, where we were able to demonstrate to two classes at different times, providing about 40 students with one of the experiments in a single day. Then, the experiment on Thermal Expansion of Liquids was carried out, and so on the following experiments were carried out: Heat Propagation Media; Change of State; Thermometry; Calorimetry and Thermology, where the experiments covered about 20 students per class. All experiments were followed by scripts containing the steps for the execution of the work, which the students performed in a very dynamic way. At the end of the experiment, the students always answered some questions that were included in the script or when asked during the experiment, with a view to their improvement and understanding of the work done.

The methodology consisted of presenting the project to the school board and later to teachers and students; reviews and bibliographic research for the preparation of didactic material; weekly planning of classes and experiments; classes with the theme Thermometry, Calorimetry, Heat Propagation, State Changes, Thermal Expansion of Solids, Thermal Expansion of Liquids, and Thermodynamics; developed in two stages: explanation of theoretical classes with presentation of the script of the experiments, and elaboration by the students themselves of experiment kits with alternative materials (soda cans, candles and others); analysis and evaluation of the results through the reports of the experimental classes prepared by the students; it also included, under the guidance of the project coordinator, to present reports to UEMA's PROEXAE and participation in academic events and University Extension Journey (JOEX) to share the results.

All phases of the project were managed by the Coordinator of the project and will obey a hierarchical organization of work according to the organizational chart planned in the project, indicated below:

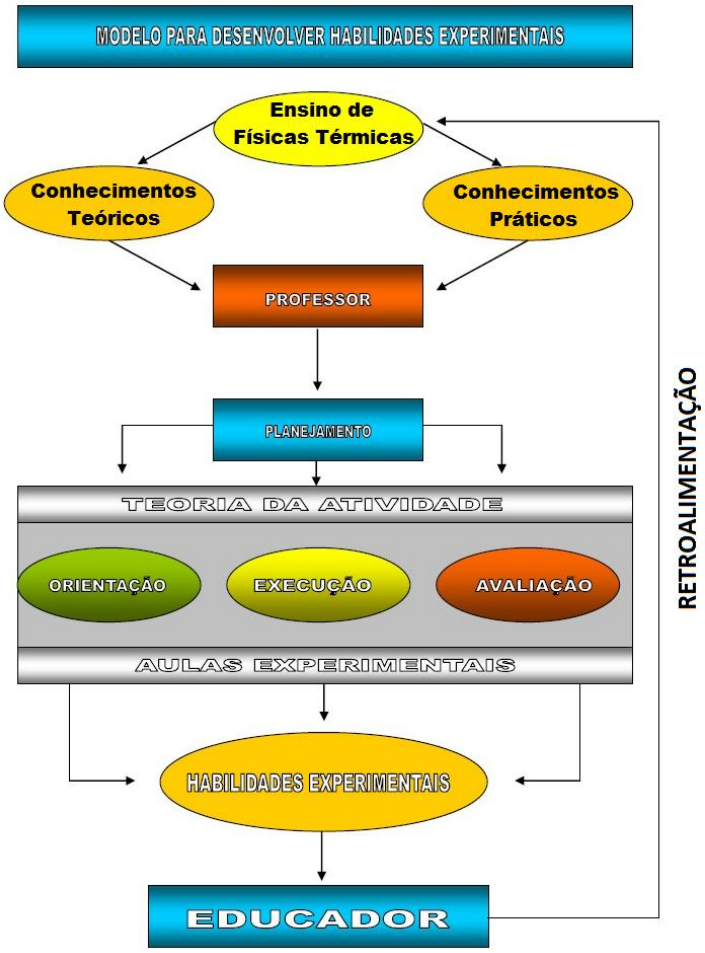
Figure 4 – Hierarchical organization chart of the project




Source: The authors.

a) Project Coordinator: it was developed by the general coordinating professor of the project, who developed activities such as: Coordinate and supervise the development of the project, ensuring the execution of the actions foreseen in the work plan; Coordinate the work of the Team involved in the project, with a view to achieving the proposed objectives; Guided and supervised the actions related to the students, monitoring the activities and forwarding the necessary documents to PROEXAE; Presented partial and final reports of the activities developed in the project; Presented accountability with supporting documents; Presented results or progress of the project in institutional events and/or extension events and finally identified in the works presented and published, the support granted by UEMA.
b) Students: There were 2 scholarship holders and 4 volunteers from the Physics and Civil Engineering degree courses that have a school coefficient higher than 7.0 (seven), who will develop the following tasks: They were in constant harmony with the project coordinator, discussing improvements with him in the activities that have been developed; They executed their work plans; Together with the project coordinator, they prepared the partial and final reports within the established deadline of the program.

Figure 5 – Developed Experimental Skills System




Source: The authors.

Therefore, our project was developed in a systemic way, through proposed activities, which provided the discovery, approximation and integration with nature through physics, enabling not only students and teachers, but man to recognize himself in the world, with the world and acting on it in a sustainable way, leaving indifference, motivated by a teaching that privileges him as a capable being. The student saw himself as the subject of his own knowledge, he appropriates it through the connection he makes between the theoretical and practical knowledge offered by human culture that relates him to the action of his own existence. In this way, the methodology applied contributed to the performance of the students, not only in the educational aspect, but providing improvement in their worldview, improving the health and income of the future professionals they will be when they finish high school, thus improving the local indicators. (NASCIMENTO-2000).

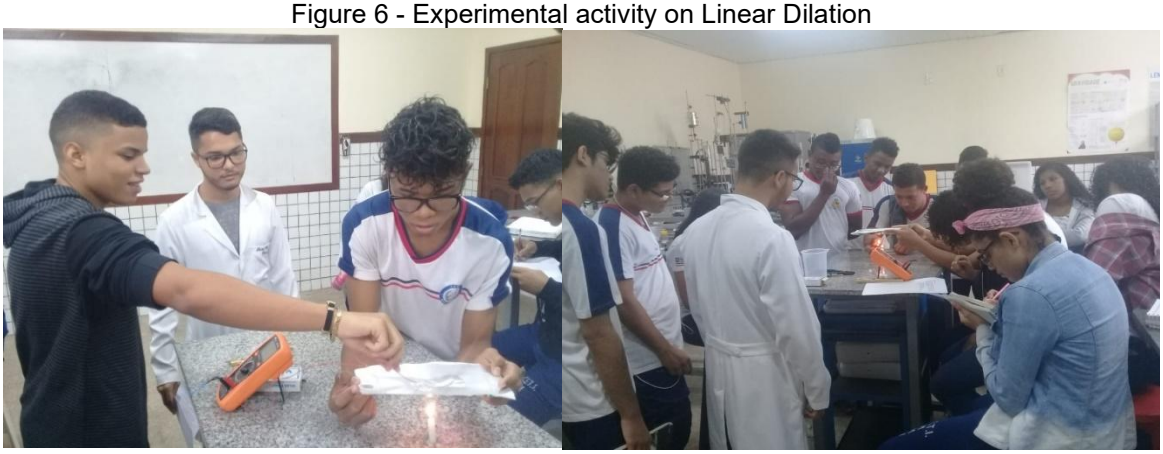
## RESULTS AND DISCUSSIONS

During the period of execution of the project with thermology experiments at the C.E.T.I - Mônica Vale school, we had as a result, the improvement in the academic performance of the students through practical classes, where they were able to put into

action everything that is seen in the theoretical classes, such as the equations and postulates of the Physics area. Throughout the practical classes, some students with the ability to relate theoretical activities with practice were verified, as well as students who showed a lot of interest in the area of Physics through questions and inquiries. However, some students had difficulties in relating theory to practice due to not understanding the phenomenon that is occurring in the activity or the equations and postulates in the theoretical activities. Most of them hoped that the application of the experiments would help in learning and make the theory visible in practice. After its completion, positive results were obtained in relation to this aspect, and of the questionnaires answered, most demonstrated a better understanding of the subjects. Another factor analyzed was the interest of the students before and after the experiment was applied. It was noted that the students started to like the discipline more after the application of the systemic model applied in the project.

It was observed that when lighting the candle both the metal and the wood heated up at its ends closest to the flame and the heat spread over its entire surface over time, causing the paraffin to melt. The thermal energy of the candle flame caused the atoms of both materials to agitate, receiving their heat (energy), the same happened with paraffin that went from a solid to a liquid state with this energy gain. This form of propagation is conduction and its main characteristic is the propagation of heat from molecule to molecule from a warmer region to a colder one. Also known as thermal conduction law or Fourier's law. It establishes that the heat flux is proportional to temperature. The conduction mechanism occurs when molecules or atoms that are at a higher temperature transfer some of the energy to nearby molecules or atoms that are at low energy. Thus, what occurred in the bar was a heat flux from the end of the highest temperature to the lowest temperature, such that the thermal conduction aims at the thermal equilibrium of the material. And so it was in all the experiments, with the students always interacting during the class through questions and discussion. Below are some photographic records of the experimental activities carried out in the project.

Figure 6 - Experimental activity on Linear Dilation



Source: The authors

Figure 7 - Experimental activity on Surface Dilation

Source: The authors

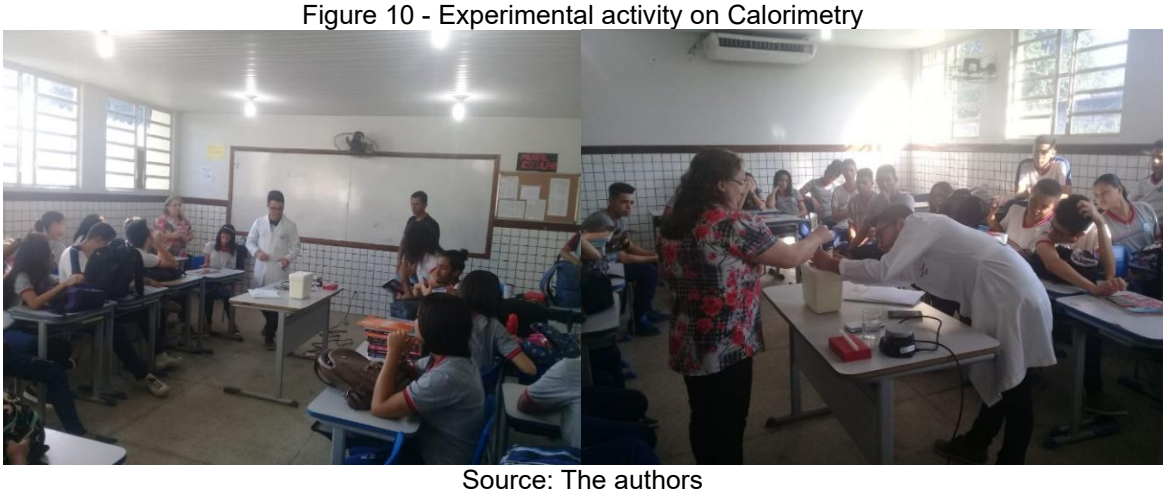
Figure 8 - Experimental activity on Heat Propagation Media

Source: The authors

Figure 9 - Experimental activity on Heat Propagation Media


Source: The authors

Figure 10 - Experimental activity on Calorimetry



Source: The authors

Figure 11 - Experimental activity on Thermology

Source: The authors

## CONCLUSION

The initial objective of the project was perfectly achieved, as the experimental activities on thermal effects within the discipline of Physics were applied in the classes of the 2nd year of high school at the C.E.T.I - Mônica Vale school in the municipality of São Luís. It was found that the use of experiments or practical classes were of great importance to complement the student's learning in the disciplines studied by him, where the purpose is to improve the students' learning in the subject of Physics. In practice, we realized that the practical activities provided the investigation and questioning of the students' previous ideas about certain scientific concepts, where they could favor conceptual change, contributing to the construction of new concepts and favoring different ways of thinking, changes in attitudes and even interconnections between Science, technology, environment and society.

The project sought in students the construction of experiments for practical classes, relating to the disciplines of Physics and Science. The experiments used low-cost materials, some of which were used several times. In this way, we seek to arouse greater interest in students in participating in classes, resuming previously studied subjects, as well as introducing new content. In addition, encouraging teachers to use practical classes as a way to teach subjects in different ways was one of the main achievements of the project.

## ACKNOWLEDGMENT

We thank the Dean of Extension and Student Affairs (PROEXAE) of the State University of Maranhão-UEMA for the development of this Institutional Program of Extension Scholarships (PIBEX), to the author-advisor Professor of our project Ubiraci Nascimento for having presented this work proposal, giving the opportunity to acquire greater knowledge and transmit it in search of greater knowledge, relationship and intellectual growth of the students.

## REFERENCES


1. Alvarez, A. A. (1998). *Modelo para a concepção do componente investigativo da profissão de agronomia* [Unpublished monograph]. ISPLT, Cuba.

2. Andrade, M. M. de. (1995). *Introdução do trabalho científico*. Atlas.

3. Bayolo, M. L., & Rivero, E. F. (1997). *Material docente básico do curso Metodologia da Investigação Educativa I*. Habana, Cuba.

4. Çengel, Y. A., & Afshin, J. G. (2012). *Transferência de calor e massa: Uma abordagem prática*. McGraw Hill.

5. Fernandez, J. R. (1998). *Introdução ao estudo da teoria do ensino problêmico*. Cuba.

6. Henandez, F. B., & Quesada, O. G. (1998). *Modelo pedagógico para a formação e desenvolvimento das habilidades, hábitos e capacidades*. Matanzas, Cuba.

7. Nascimento, U. S. (2000). *A formação de habilidades experimentais no professor de física do ensino médio em São Luís - MA* [Master's dissertation, Convênio UEMA/IPLAC]. Repositório UEMA.

8. Ovigli, D. F. B., & Bertucci, M. C. S. (2009). A formação para o ensino de ciências naturais. *Ciências & Cognição, 14*(2), 194–209. http://www.cienciasecognicao.org

9. Reginaldo, C. C., Sheid, N. J., & Güllich, R. I. da C. (2012). O ensino de ciência e a experimentação. In *IX ANPED SUL - Seminário de Pesquisa em Educação*.

10. Santos, R. de S., Lopes, R. P., & Feitosa, E. da S. (2015). Uso de experimentos virtuais no ensino de física. In *8º Congresso de Extensão Universitária da UNESP* (pp. 1–5). http://hdl.handle.net/11449/142736

11. Zayas, C. A. (1989). *Fundamentos teóricos da direção do processo docente-educativo na educação superior cubana*. Habana, Cuba.