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FROM THEORY TO PRACTICE: INVESTIGATING UNITS OF MEASUREMENT IN THE CLASSROOM

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Anne Caroline Cabral Rodrigues Cortez[1] and Roberta Veloso Garcia[2]

ABSTRACT
Contrary to what many think, classroom experiences and investigations go beyond the physical laboratories within the school. The present work describes a demonstration of how it is possible to use simple materials, present in the daily lives of students and in their own homes, to carry out experiments. The objective is to relate the units of measurement involved in volume calculation and highlight the importance of standardizing these units throughout the history of humanity, recognizing Science as an activity that produces knowledge and that has developed over time in response to human needs. The research was carried out during Mathematics classes, with the participation of 41 students from the 5th year of elementary school in the early years of a private school. The research evidenced the importance and benefits that the investigative class provides to the student's learning process. The results show that it is possible to carry out experiments and investigations in the teaching of Mathematics, promoting a teaching connected with reality and with situations present in the daily lives of students.

Keywords: Experimentation. Research. Units of measurement. Mathematics Teaching.

[1]Master of Science
Focus School/Guaratinguetá
E-mail: annecarol.cr@gmail.com
LATTES: http://lattes.cnpq.br/3072955773656658
[2]Associate Professor in Calculus I and II
School of Engineering of Lorena
E-mail: robertagarcia@usp.br
LATTES http://lattes.cnpq.br/5107846466535413

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INTRODUCTION

Scientific research should be part of the school daily life in an accessible and meaningful way, contributing to the development of knowledge and learning. Several educational practices can be developed for this purpose, and it is up to teachers to seek strategies that favor the realization of proposals aimed at the construction of knowledge by students. In general, classes in elementary school in the early years are characterized by valuing students' curiosity, enthusiasm, and prior knowledge, in order to favor meaningful learning (BARDI, 2020).

According to the National Common Curriculum Base (BNCC), the teaching of Science should provide an understanding of the world through scientific visions, through scientific knowledge produced throughout the history of humanity, developing investigative practices and their procedures.

This scientific knowledge must be built from various practices in the classroom, and not only in experiments carried out in laboratories. It is essential to offer students learning opportunities that encourage curiosity, enabling the formulation of questions and the organization of methods to obtain, analyze and structure ideas from these investigations (BRASIL, 2017).

When it is proposed that the student only observes an action or a phenomenon, this contributes little to his learning process. This process can be more effective when the student is instigated through situations in which they can put content into practice, acquiring the habit of debating the results of their own practices and experiences (BRASIL, 2014).

According to Bissoloti and Titon (2022), high school students have difficulties in Geometry because they have gone through Mathematics teaching processes aimed at memorizing formulas, concepts, and definitions, in which the student has a passive role in their own learning. The authors state that the absence of the use of concrete materials, investigations and experiments in the teaching of the discipline is evident. They also disagree that "Geometry presented only with formulas ends up confusing students, as it does not allow the visualization of figures and solids, along with the properties they will explore and the calculations they will perform" (BISSOLOTI and TITON, 2022, p.2).

The National Pact for Literacy at the Right Age of the Ministry of Education (Brasil, 2014), in relation to work with content related to the quantities of measurements, highlights

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"the absolute need for work in which children are mobilized in effective measurement practices".

To relate the units of measurement involved in the calculation of volume and highlight the importance of standardizing these units of measurement, the question arises, "how can the use of simple everyday materials, combined with investigative practices in the classroom, contribute to the meaningful learning of mathematical concepts?

Thus, it is essential to provide situations in which the student realizes the importance and use of physical properties and measurement quantities in everyday life, showing how humanity has developed this knowledge throughout history, in response to its needs. Emphasizing the importance of these quantities and their standardization can enable broader and more meaningful learning.

EXPERIMENTATION AND RESEARCH IN MATHEMATICS

The teaching of Mathematics largely adopts an approach in which the teacher only transmits the content present in books or handouts, through one-way communication. In this model, students often reproduce or replace values in formulas in a mechanical way, without understanding the meaning behind the concepts, making learning disconnected from its context and not very meaningful (ALMEIDA and MALHEIRO 2018). According to Santos et al. (2017), the justification for this mechanization in the teaching process lies in the lack of adequate infrastructure, such as laboratories, the scarcity of materials and even the limitation of time available to deepen the contents.

Penha et al. (2009) highlight the importance of conducting experiments in the development of scientific literacy, emphasizing that the student should not be just a passive observer or a mere manipulator of materials without reflection. For the construction of knowledge to occur in a meaningful way, it is essential that the student is questioned and encouraged to reflect critically. In addition, the authors point out that, historically, laboratories have been used as tools to motivate students through practical demonstrations. However, as Bassoli (2014) argues, many of these activities are proposed with the aim of saving time, limiting the active participation of students and reducing interactivity. Thus, laboratories end up serving only as a starting point, without being characterized as a true process of experimentation and investigation.

To transform this vision of experimental activities in the classroom, the teacher needs to seek new knowledge, plan and apply methodologies aligned with the students' reality. This includes the use of accessible materials, as well as the exploration of alternative spaces and means that enable a dynamic and engaging class. In this way, students are encouraged to mobilize previous knowledge and discover new concepts, promoting active, investigative and meaningful teaching. This approach not only contributes to the understanding of the world around them, but also forms critical and reflective individuals, capable of analyzing, confronting information, and arguing in a reasoned manner (SANTOS et al., 2017; ALMEIDA and MALHEIRO, 2018).

An effective strategy to avoid rote learning, characterized by a lack of connection with previously assimilated knowledge, is the incorporation of the history of scientific knowledge into teaching. Massoline (2019, p. 13) emphasizes that "by working through a historical approach to the contents studied, scientific knowledge is brought closer to the student's cognitive universe". This connection, especially in areas of the exact sciences, highlights the relevance of scientific knowledge throughout the history of humanity, showing that it was built from questioning, observations, and collaborations. In addition to arousing the interest of students, this approach favors motivation for classes (MASSOLINE, 2019).

Thus, methodologies that involve experimentation and investigation transcend the simple transmission of knowledge and promote interdisciplinarity. By taking a more active role in their own learning, students develop essential skills, such as the ability to question, observe, elaborate arguments, and reach their own conclusions, becoming protagonists in the process of constructing knowledge.

METHODOLOGY

Based on the curiosity and questions raised by the students during the class, a didactic sequence was elaborated that involved the measurement, calculation and relationship between units of measurement of length and capacity. This approach provided an interdisciplinary work with other areas of knowledge, essential for meaningful learning, allowing students to perceive the presence of science in various everyday situations.

The present research is qualitative in nature, with data collection carried out over three classes of 50 minutes each. The study included 41 students from the 5th year of elementary school – early years, from a private school.

The investigation sought to deepen the understanding of the use of experimentation and investigation in Mathematics classes, with emphasis on the teaching of volume calculation. The relationships between the units of measurement directly linked to the theme, such as length and capacity, were analyzed.

The activities were organized in three stages, adapted to the content and the handout material adopted by the school. The students had previously been introduced to the formula for calculating the volume of prisms with a rectangular base. However, there was difficulty in understanding and assimilating the relationship between the values obtained and the amount of liquid

To make this relationship clearer and provide greater playfulness to learning, an activity was developed in which the main aspects are presented in Chart 1.

Chart 1 - Structure of the activity that relates units of measurement

1ST STAGE	
RELATIONSHIP OF UNITS OF MEASUREMENT OF LENGTH AND CAPACITY	
Materials	• 1 plastic pot (prism-shaped with a square base); • 1 ruler; • 1 measuring cup (or other container) graduated in milliliters • Paper and pencil
Actions and Questions	• What data is needed to find out the volume in square centimeters of the plastic pot? • What calculations should be made? Students should measure the dimensions (height, length and width) of the pot and calculate the volume. Before measuring the capacity in milliliters with the measuring cup, users should be aware of the ratio: $1cm^3 = 1$ ml; • How to relate units of length to units of capacity? Students should fill their containers with water and measure capacity in milliliters.
Observation	Students should already be aware of the formula for calculating volume and the relationship between units.

Source: The authors

The scientific knowledge developed by humanity throughout history is fundamental to modern life, being present in various aspects of daily life. However, many students use objects and technologies without understanding the scientific principles that underlie their operation. To promote this understanding, the second stage of the activity seeks to establish connections between different areas of knowledge through interdisciplinary content, according to the sequence presented in Chart 2.

Chart 2 – Structure of the activity that relates the volume to the amount of matter displaced

2ND STAGE	
VOLUME SHIFTED BY AN OBJECT	
Materials	• 2 glasses with the same volume of water; • 1 object with high density.

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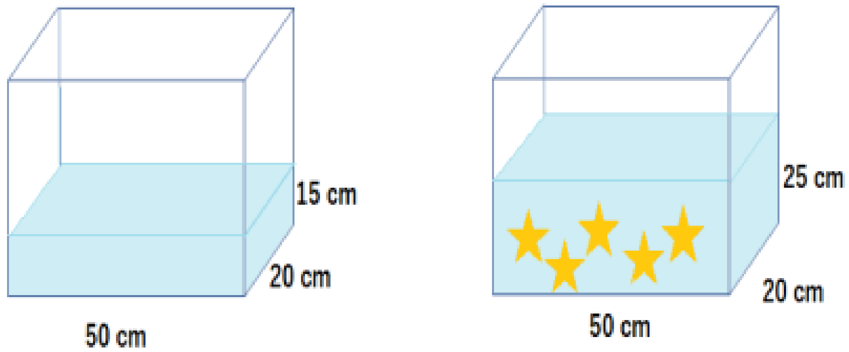
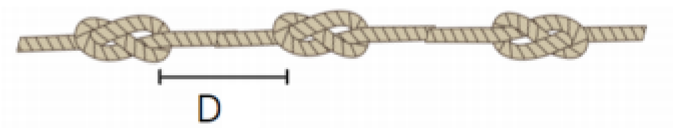
Actions and Questions	• What would happen to the volume of water if the object is placed inside the glass? The students' answers can be represented by drawings, written or oral in a conversation circle. Present the video of the story "Archimedes and the King's Crown". • Interdisciplinary work: contents of Science, History and Mathematics. Confirmation (or not) of the hypotheses raised about the volume of water, asking students to place the object in one of the glasses.
Exercise	What was the volume displaced by each object? Consider that all objects (represented by the stars) are equal. 

Source: the authors

Finally, the last stage, presented in Chart 3, proposes the adaptation of content from the students' didactic material, with the objective of establishing connections between learning and their daily lives. In this context, the importance of the invention of decimal numbers and the standardization of units of measurement throughout the history of humanity is highlighted, rescuing, as a starting point, the measuring instruments used by the Egyptians.

Table 3 – Structure of the activity that provides measurement like the Egyptians

3RD STAGE	
MEASURING LIKE THE ANCIENT EGYPTIANS	
Materials	• A piece of string
Actions and Questions	Read the text: "Like the Ancient Egyptians" Do as the ancient Egyptians did. Take a long string and make a minimum of 10 knots equally spaced apart. We'll call the distance between two nodes D and this will be the unit of measurement  that we're going to use. Measure some objects available in your school supplies and record the measurements. • Was it possible to measure the objects with the unit of measurement using only natural numbers? Explain.

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	• How can you adjust your string so that you can measure objects more accurately? Presentation of the INMETRO video: "Measures present in everyday life and the importance of science called Metrology". • According to the INMETRO text and video, why is the concept of measurement so important in the history of Mathematics?

Source: Created by the authors with data extracted from Bardi (2020).

RESULTS AND DISCUSSION

This chapter aims to analyze and interpret the results obtained in the study, focusing on the implications of the findings in relation to the research objectives and the hypotheses formulated. The research sought to investigate how the units of measurement involved in the calculation of volume can be taught to students and highlight the importance of standardizing these units.

Before starting the activities, the students were very interested and curious as soon as the material for the next classes was requested.

When the class began with the activities of the first stage of the application (Chart 1), there were already many doubts about it, highlighting a particularly excited comment from one of the students:

Student: "... Teacher, I'm feeling like a real scientist."

This speech of the student demonstrates motivation and involvement, bringing emotion and meaning to the learning moment provided. Initially, some students had difficulties locating the dimensions of height, length and width in the plastic pot. This can be explained by the fact that in the theoretical exercises the measures are presented and they are conditioned to multiply the three values presented.

An important point observed was the questions by the students about what to do with the rounded corners, or different widths at the top and bottom of the pots. They were then asked to try to figure out alternatives to solve this problem. The students suggested assuming approximate values.

After all the students were able to measure the measurements and calculate the volume of the pot, the transformations from cubic centimeters (cm^3) to milliliter (ml) were carried out according to the relationships that the didactic material had already presented.

This moment was also one of discoveries, especially for students who were using ice cream tubs and reached results such as 1,700 ml or even higher values. Although they had already performed calculations that resulted in even higher capacities, they were surprised to realize that these values represented much larger volumes of water than they imagined for a relatively small pot. Many were under the impression that they had made errors in the calculations, as can be seen in the following statements:

Student: "... aunt, I don't know, this number is strange, what a large number, I think I made a mistake in the comma counts".

Student: "... Teacher is a lot of water, it won't fit in this little pot".

To clarify doubts about the calculations, the students were instructed to check the results using a calculator. When they discovered that the calculations were correct, they were soon faced with another challenge: how to measure the capacity of jars that exceeded 500 ml, if the measuring cup did not hold this amount. Some students quickly realized the necessary procedure, while others needed guidance to understand how to solve the situation.

At the end of the measurements, some students faced problems and expressed their concerns, as follows:

Student: "... Our experiment didn't work out!"

Student: "... I knew I had made the wrong calculation..."

Student: "... the value doesn't add up."

The students were frustrated, because the values obtained in the measuring cup did not coincide with the calculated measurements. The question then arose: why did this happen?

It was necessary to carry out new interventions for them to reach the conclusion that the discrepancies were due to the rounding of the measurements, caused by the rounded corners of the containers. Some students recalled that, when buying certain products, the containers do not come completely full and highlighted the need to use more precise measuring instruments to obtain more accurate calculations. Figure 1 presents photos taken by the authors during the activity, recording the moment when the students took the measurements and compared the values found in the calculations with those of the measuring cup.

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Figure 1 – Moment of measurements taken by the students

Source: The authors.

In the second stage (Chart 2), the students remained enthusiastic and showed great motivation when they needed to prepare manipulable materials for classroom activities. Only by having the requested objects in hand, the students were already able to identify what would happen in that experiment. When asked what would happen to the volume of water in the glass when they placed an object inside, they all confidently replied that the water would rise. Next, the students watched the video about the story of Archimedes, and the students were interested and surprised to realize how such a simple idea had such a significant impact on everyone's lives. After the video, the students were asked to test their hypotheses by placing the objects in the glass of water to verify that they were correct.

Figure 2 shows a student who, when he did not have any object available to dip into the glass, used his own body to test the hypothesis, just as Archimedes did.

Figure 2 – Student testing his hypothesis that part of the volume of water rises when a body is inserted into the container with water.

Source: The authors

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During this activity, several questions arose, covering several disciplines, especially the concepts acquired in Science and History classes, related to the physical properties of materials.

The performance of the volume calculation exercises, after the two previous stages, occurred more easily, with a significantly greater number of students correctly interpreting the problems and achieving accurate results.

In the third stage (Chart 3), the experiment proposed in the workbook was adapted. Students should bring a piece of string with a knot from home. However, when explaining the task, some students reported that they did not have string or rope to carry out the experiment. The following question was raised: "Did the Egyptians or other ancient peoples have string? What could we use for the same purpose?"

The number of students who completed the activity was reduced, with only 25 of the 41 students turning in the assignment.

The materials used to reproduce the measurement techniques of the Egyptians were surprising. After measuring the objects with the measuring instrument they had built, the students answered two questions. When asked, "*Was it possible to measure the objects with the unit of measurement of the distance between us using only natural numbers? Explain*", 19 of the 25 students answered negatively, while 6 showed agreement, as can be seen in Chart 4.

Table 4: Students' answer about whether or not it is possible to measure objects with the unit of measurement of distance between us using only natural numbers

They answered "Yes"	They answered "No"
It depends on the distance of the nodes.	Because it has a decimal number.
It depends on the object.	The rope has no exact number.
By the approximate size of the objects measured.	**The instrument has no fractional numbers**

Source: The authors

Expressions in bold justify most of the students' answers. Some materials used by the students are presented in Figure 4.

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Figure 4 – Diversity of materials used in step 3

Source: The authors

It was noted that most students have a clear perception of the origin of the measurements, especially when they relate them to decimal or fractional numbers. They can also understand that the method used by the Egyptians is only applicable to specific situations, which demonstrates the need to improve the tool for greater accuracy.

As for the question "*How can you adjust your string to measure objects more accurately?*", the most common answers suggested tying knots in the string with the same distance and the use of a ruler.

This question revealed that the students are already familiar with the concept of a standardized measurement instrument in their daily lives. The realization that a tool that offers greater accuracy would easily solve the problem demonstrated how a simple object can have a significant impact on everyday situations in society.

Regarding the question "*Why is the concept of measurement so important in the history of Mathematics?*", the most recurrent answers are presented below:

1. *Because it is part of our daily lives and we need to use it to solve everyday problems.*
2. *For creating the concept of unnatural numbers.*
3. *To measure accurately and not make mistakes in the calculations.*
4. *To measure things in different ways.*

Finally, it was possible to perceive that students recognize scientific knowledge as an evolution of human observations and needs. They understood that everything they learn today about units of measurement is linked to stories that have emerged in solving practical problems. In this way, they began to perceive mathematics beyond formulas, as a tool present in real situations.

In addition, they understood why the calculations performed in the first stage presented differences, highlighting the importance of accuracy not only in the measurement process, but also in several areas, scientific or not.

FINAL CONSIDERATIONS

By developing and applying activities that encourage students to put into practice the concepts learned in handouts, it is not just a motivating or different class, but an opportunity to highlight the importance of the knowledge they are acquiring and how it applies to various everyday situations, often closer than they imagine.

These activities allow us to show that, to arrive at a certain formula or standard, a large amount of science was applied, involving studies, experiments and investigations. They highlight the contribution of scientists throughout history, showing that knowledge does not arise in isolation, but is the result of a continuous process of discovery and improvement.

The possibility of carrying out experiments and investigations represents a fundamental resource for teachers to plan classes with methodologies that place students in the role of builders of their own knowledge, using elements that are part of their reality. This compensates for the absence of experimental classes that were previously seen as exclusive to physical spaces, such as laboratories within schools. The space for carrying out the experiment is no longer just the laboratory or the classroom, and starts to encompass the home, the street, nature and other places frequented by the students, which become favorable environments for carrying out experiments. These spaces are part of the students' daily universe, facilitating their interest and involvement.

Experimentation and investigation in Mathematics classes, with the manipulation of objects and measuring instruments, propose to students the development of problem-solving skills and the use of pre-established formulas. This approach encourages interpretation and argumentation about phenomena, promoting independent thinking and allowing a deeper reflection on the contents studied.

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