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Why do astronauts "float"? The representation of the principle of weightlessness in experiments developed for high school

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ABSTRACT

Many students leave high school without being able to identify basic physics knowledge in their daily lives, and when they do, most of the time, they are not able to transpose this knowledge to situations that are distant from their daily lives. Thus, we present in this work a proposal to develop the concept of weightlessness for high school, through three experiments: i) in a real elevator, ii) in a miniature elevator, built to be used by teachers in classrooms and iii) the construction of an experiment that uses an electronic circuit which aims to demonstrate, in an analogous way, the effects of weightlessness on the astronauts of the Space Station. For this, we went through a brief review of the concept of weightlessness and a discussion about experimentation in physics teaching, addressing the importance of these practices when concerned with the teaching of science and scientific activity. Finally, we suggest a didactic procedure containing these experiments, using some assertions about the teaching of the scientific method. Thus, we consider that experimental activities, in addition to being designed to understand a particular content, it should always be thought of, above all, in the context of the construction of scientific knowledge.

KEYWORDS: Experimentation. Physics Teaching. Epistemology.

INTRODUCTION

Experimentation is part (or should be) of every science teacher's daily life, especially if the aim is to illustrate abstract concepts in the classroom. For Binsfeld and Auth (2011, p. 04) "experimentation is seen as a didactic tool to assist in the understanding of knowledge, in the sense of giving meaning to concepts". The abstraction necessary many times for the understanding of a determined subject, can become an obstacle for a clear interpretation of the subject to which it is being studied, being necessary other methods of approach. Thus, experimentation can be a tool that enhances the significant learning of the exposed content.

However, physics classes focused solely on content in high school are usually seen as monotonous and tiring, facilitating the dispersion of students' attention. According to Delizoicov and Angotti,

> the experiences generally arouse a great interest in students, in addition to providing a situation of investigation. When planned, [experiences] constitute particularly rich moments in the teaching-learning process (1994, p. 22).

Thus, experimental practices become great allies, both for the teacher and for the student, because normally the experiment is linked to the student's curiosity and this assertion can be introductory to meaningful learning.

However, the current paradigm of research is found in the literature, pointing out that the teaching of physics, and above all, the experimentation in the teaching of physics, does not adequately demonstrate the process of construction of scientific knowledge. And so, the experimentation that could come to elucidate possible abstractions of specific contents, ends up neglecting all the development that the scientific activity carried out to obtain such an understanding of the world. It is in this context that many authors encourage epistemic experimental practices, that is, with concerns related to the process of developing scientific knowledge (RAICIK; PEDUZZI, 2015).

With the potential to instigate students' curiosity inherent to experimentation, the teacher has in his practice a greater possibility that his didactic transposition is carried out in a more adequate way, that is, that students learn exactly (or more approximately) the content that if you want to teach. With this tool in hand, we understand that the intention of working not only on science content, but also on science, is crucial for more adequate physics learning.

In order to suggest experimental practices concerned with the above scenario and invite physics teachers to reflect on their experimental practice, we present below a development of the concept of weightlessness through the construction of three experiments, as well as the elaboration of a possible didactic procedure elucidating not only the content to be proposed, but also the epistemic discussions that can embark on it.

A BRIEF REVIEW OF THE PRINCIPLE OF WEIGHTLESSNESS

In the context of science education, it is possible to perceive that there are several themes and phenomena that have the potential to stimulate creativity and make the student more active in their learning process. The weightlessness principle can be an example of this, if we think that one of the things it explains is the nature of astronauts floating on the International Space Station (ISS). Weightlessness can be described as the apparent absence of weight and is also evidenced in Figure 1.

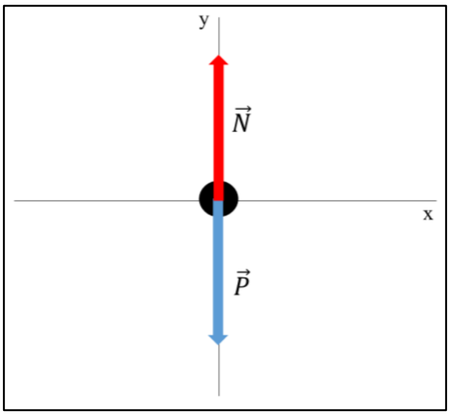
Figure 1 – Stephen Hawking in an airplane experiencing the effects of free fall.

Source: Zero Gravity Corporation (2017).

This phenomenon, which also occurs on the Space Station, was conceptually introduced by Newton in the 17th century, when he asked about the trajectory of a cannon ball that was shot horizontally. As the rate of fire increased, he thought, the further its range would be. Eventually, the cannonball would reach a tangential velocity sufficient to create a balance between the gravitational force and a fictitious force of inertial origin (centrifugal force), thus entering Earth orbit (CECCONELLO *et al*., 2021). Next, we will demonstrate analytically the reasons for the "float" effect to appear under these conditions.

An analogy of this phenomenon can be represented in an elevator, although it does not have the effect of zero gravity. The initial and final accelerations give the observer inside the elevator a decrease and an increase in weight depending on its starting point. In figure 2, you can see a free body diagram (FBD) of a person inside an elevator at rest.

Figure 2 – Free body diagram



Source: The authors (2022).

In the equilibrium situation the sum of the forces acting on the system is equal to zero ($\sum \vec{F} = 0$), that is, $a = 0$. In figure 2, the observer will be subject to the action of two forces, one being a field force, given by the weight force ($\vec{P}$) and another of contact, due to the normal force ($\vec{N}$). In the situation of equilibrium in the plane, $\vec{N}$ assumes, in module, the same value as $\vec{P}$, but it should be noted that they do not form an action and reaction pair.

In a system like this, it is common to find presentations of Newton's third law representing the reaction of the weight force as the normal force. This is incorrect. Newton's Law of Universal Gravitation tells us that the Earth "pulls" us towards its center, but that we also pull the Earth towards our center of mass. Therefore, the reaction of an action must be applied to the body that produces the action, that is, on Earth, discrediting the normal force as the reaction of the weight force.

Taking into account the above considerations, we have:

$$\sum \vec{F} = 0$$

$$\sum \vec{F} = \vec{P} + \vec{N}$$

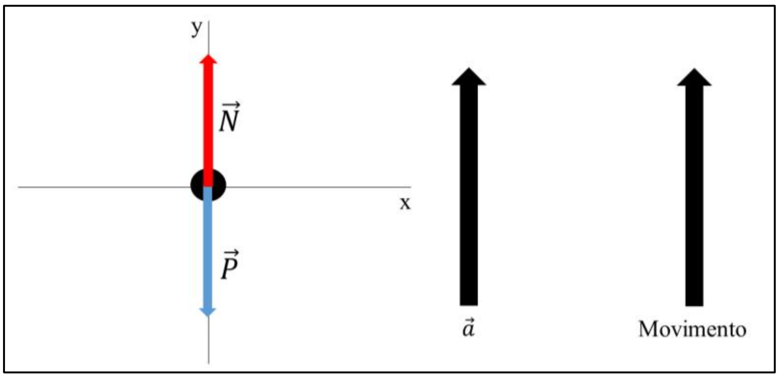
$$P - N = 0$$

$$\boldsymbol{P = N}$$

Let us now consider an observer on a scale inside an elevator and two situations: elevator accelerating up and elevator accelerating down. The observer will continue under the action of the weight and normal forces, however, we must take into account the elevator's acceleration and its direction. The normal force will assume the role of "apparent weight", and its value will be given by the reading of the balance multiplied by the local acceleration of gravity, since the balance will not register the weight of a person (in Newtons), as common sense calls it, and yes, the mass (in kilograms).

In case the elevator starts moving in an accelerated way ($a \neq 0$) towards the positive y direction, the normal force will have a contribution from this acceleration, being $\vec{N} > \vec{P}$, in this case the FBD changes, as shown in the figure 3.

Figure 3 – Free body diagram, with an accelerated elevator motion



Source: The authors (2022).

Applying Newton's second law, since we have accelerated motion:

$$\sum \vec{F} = m.\vec{a}$$

$$\sum \vec{F} = \vec{P} + \vec{N}$$

$$N - P = m.a$$

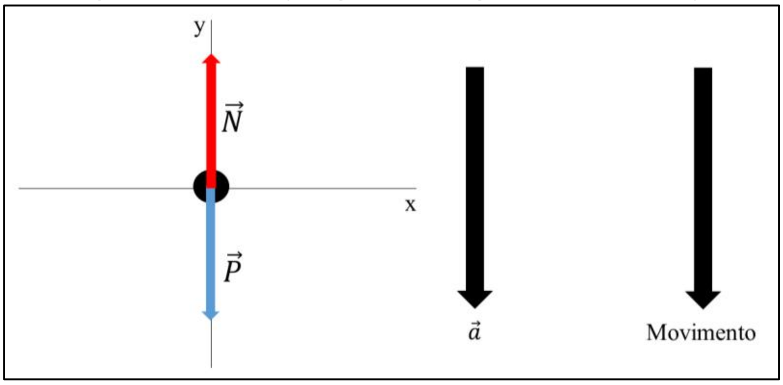
$$N = P + m.a$$

$$\boxed{\boldsymbol{N = m.(g + a)}} \qquad \textbf{[Eq. 1]}$$

Where $\vec{N}$ and $\vec{P}$ are in Newton. In this case, there is acceleration of the elevator and, consequently, of the observer inside. Therefore, this acceleration will be added to the acceleration of gravity and this allows a sensation of greater apparent weight (HALLIDAY *et al.*, 2008).

In the situation where the elevator starts from rest in the negative y direction, $\vec{N}$ will be less than $\vec{P}$, as the acceleration will be in the opposite direction. In this case, the FBD changes (figure 4), along with its equation.

Figure 4 – Free body diagram, starting from rest at the top



Source: The authors (2022).

$$\sum \vec{F} = m.\vec{a}$$

$$\sum \vec{F} = \vec{P} + \vec{N}$$

$$P - N = m.a$$

$$N = P - m.a$$

$$\boxed{\boldsymbol{N = m.(g - a)}} \qquad \textbf{[Eq. 2]}$$

In this case, there is a subtraction of the acceleration of gravity with the acceleration of the elevator, which will result in the observer who is inside the elevator feeling lighter, with a decrease in apparent weight.

Although this experiment is not defined by the principle of weightlessness, since it is defined by the absence of apparent weight and not its decrease, we can imagine that from the moment the elevator cables break, it starts to fall in free fall, that is, the acceleration of the elevator is equal to the acceleration of gravity. The representation is expressed as follows:

$$\vec{a} = \vec{g}$$

$$\sum \vec{F} = m.\vec{a}$$

$$\sum \vec{F} = \vec{P} + \vec{N}$$

$$P - N = m.g$$

$$N = P - m.g$$

$$N = m.(g - g)$$

$$\boxed{\boldsymbol{N = 0}}$$ **[Eq. 3]**

Calculations have shown that when a person is free-falling inside an elevator (and also inside a Zero Gravity Corporation plane) their normal force is zero, which results in them floating around inside the establishment.

The same is true of astronauts on the international space station. Orbiting the Earth, these are subject to gravitational force, so they are in free fall. However, unlike the elevator experiment, the space station has a uniform rectilinear motion with a velocity that is tangential to its orbit.

> The gravitational force of the Earth acting on the satellite is always directed towards the center of the Earth, so if the trajectory is circular (it can be elliptical), the force will be normal to the trajectory and can be calculated by the expression $F = mv^2/R$. As the law of universal gravitation is given by the expression $F = GMm/R^2$, it follows that $v = (GM/R)^{1/2}$, where R is the distance taken from the center of the Earth to the satellite, G is the Universal Constant of Gravitation, M is the Earth's mass, m is the vehicle's mass, F is the force of gravity and va orbital velocity. This expression allows us to say that around 300 km of altitude a satellite will have a speed close to 7.7 km/s or about 27 thousand km/h (REIS *et al.*, 2008, p. 05).

With this orbital velocity v, the Space Station, as well as the astronauts and everything inside, finds a balance between a fictitious force of inertial origin (Centrifugal Force) that tends to push them away from the planet and the Gravitational Force that tends to bring them closer. them from Earth. However, using the same equation above for the Law of Universal Gravitation, it is possible to disprove something that is misunderstood by the general population:

$$F_g = \frac{GMm}{R^2} = mg$$

$$\boxed{\boldsymbol{g = \frac{GM}{R^2}}}$$ **[Eq. 4]**

Substituting the values for the Earth's mass M = 5, 98 x10^{24} kg and the Earth's radius plus the height of the space station from the surface R = rT + h = 6371 + 300 km, into Eq. 4, the gravitational acceleration of 8.7 m/s² is then obtained.

That is, although it is less than the gravitational acceleration at the surface, the fact that the space station is farther from the center of the Earth, or in "space" as commonly proclaimed, does not justify the floating of astronauts and objects within it. Much less does it go back to microgravity or the absence of gravity, because, as we have seen, at that time gravity has considerable intensity. The concept of zero gravity, then, corresponds directly to observers and/or objects in free fall, whether in the example of the elevator with the broken cables or with the space station in gravitational equilibrium.

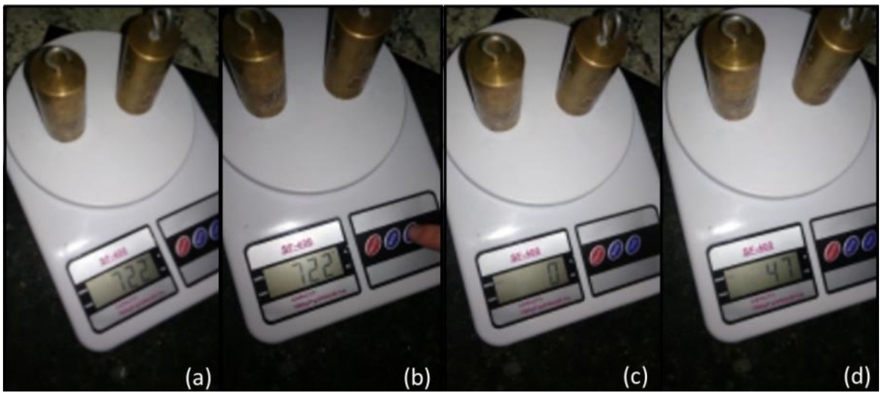
Thus, starting from an example closer to the student's daily life (the elevator), the physics teacher has the possibility of approaching a topic that is distant from the student (space station) and also from a good part of the population in general. Next, we will see the construction of experiments involving the physics discussed here.

THE CONSTRUCTION AND RESULTS OF THE EXPERIMENTS

The experimentation boils down to three distinct but interconnected stages. Initially, in a full-size elevator, we can use a common scale capable of measuring the mass of a person or a scale of smaller capacity together with an equivalent mass. The scale we used had a capacity of up to 7.0 kg and the mass used was 0.722 kg (figure 5a). We carried out the experiment in the two-story building of the Instituto Federal de Santa Catarina, Campus Jaraguá do Sul – Centro. After placing the set inside the elevator, the scale was zeroed (or tared) for better visualization (figure 5b-c) and the elevator was activated. And then, we tried to record with a camera the effects of the elevator's acceleration on the mass positioned on the scale.

As a result, we observed that there was a significant variation in relation to the original mass, which after starting the elevator movement, had a variation around 0.047 kg (figure 5d), obtaining an approximately equal value, but with opposite sign for when the elevator decelerates close to its destination. It is worth mentioning that the mass of the object did not change, the variation in kilograms that is verified is due to the balance showing the value on the display as the weight in Newton divided by the acceleration of gravity. This experiment was repeated five times and, using the same mass on the scale, we found the same value in all repetitions. In view of this, we were careful with the related systematic errors, since physical measurements can always present a certain degree of uncertainty. To reduce such errors, we try to keep this uncertainty at tolerable levels, enabling an acceptable final analytical result.

Figure 5 - (a) At rest, (b-c) Scale being zeroed, (d) Apparent weight variation with the elevator activated



Source: The authors (2022).

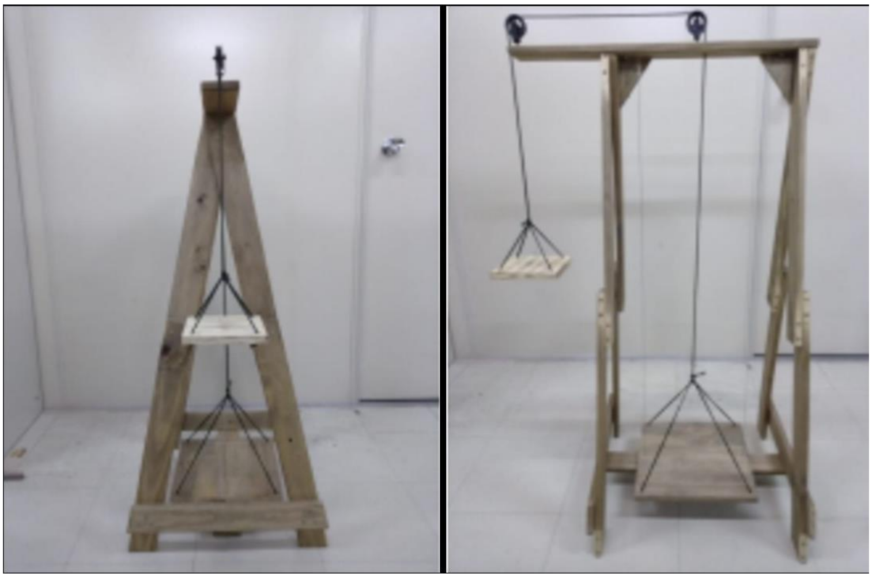
Figure 5 was acquired through a printscreen of the video, available at https://www.youtube.com/watch?v=OrP94tLgQ2o&feature=youtu.be&ab_channel=Experimentospmge. With the video, we can also observe that for a brief moment of its transition, the scale does not register any mass. This is due to the fact that in this period, the elevator runs its path uniformly.

Using the Fundamental Principle of Dynamics, we calculate the value of the elevator's acceleration, which is equivalent to 0,637 m/s^2. With this acceleration, it was possible to verify and compare the values obtained experimentally and theoretically, and both values for the ascent and for the descent coincided equally with its application. In terms of visualization, the value of the weight of the object placed on the scale is approximately 7.08 N, so, with the elevator going up and down, its weight is, respectively, 7.53 N and 6.61 N. from the elevator's acceleration, it is possible to calculate the apparent weight for any mass that is placed inside the apparatus.

The second experiment was based on the construction of a miniature elevator so that it would be possible to take the experiment to the classroom. The elevator was essentially produced with reused wood. For the assembly of the sides, we used pine wood in strips, assembling the structure with the aid of screws, which has the total dimensions of 1.15 m in height and 0.63 m in width.

With the experiment set up, at the top we placed two pulleys in order to suspend the two mobile shelves of the elevator, one being the central and main tray that contains a miniature scale with a precision of 0.1 g and that will be responsible for generating the difference. of weight that we expected to obtain, and the second tray where the counterweights that generate the movement in the elevator are placed. For all the movement, a string was used that is linked to the two shelves, with the tray with the scale at one end and the one with the counterweight at the other. For its operation, the procedure is simple: the scale was positioned on the main tray next to a mass and then enough weights were placed on the secondary tray, causing the main tray to rise and the positioned balance to demonstrate a weight variation for the mass used. The experiment set up can be seen in Figure 6.

Figure 6 – Miniature Elevator



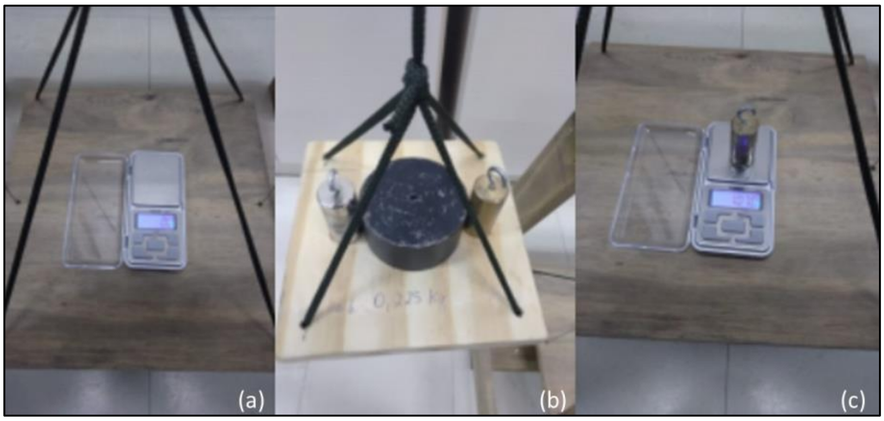
Source: The authors (2022).

After completing the construction of the miniature elevator, we sought to measure the mass of the two mobile shelves in order to disregard this value during the calculations that followed, simplifying the mathematical manipulation of the whole. For this experiment, as previously described, we used a balance with a precision of 0.1 g (figure 7a). This is due to the fact that a mass of only 0.107 kg was used on it, in this case there is only a brief variation in apparent weight because it is a low value for mass.

To counterbalance and make possible the movement of the main tray, the secondary tray had a mass difference equivalent to 0.520 kg (figure 7b).

Considering that the weight of the mass on the scale has a value of approximately 1.05 N (figure 7c) and, when it starts to move due to the abandonment of the mass in the secondary tray, it presents a value for the weight variation of the order of 0.024 N, this value being obtained experimentally.

Figure 7 – (a) Precision balance; (b) Secondary tray masses; (c) Mass on the precision balance



Source: The authors (2022).

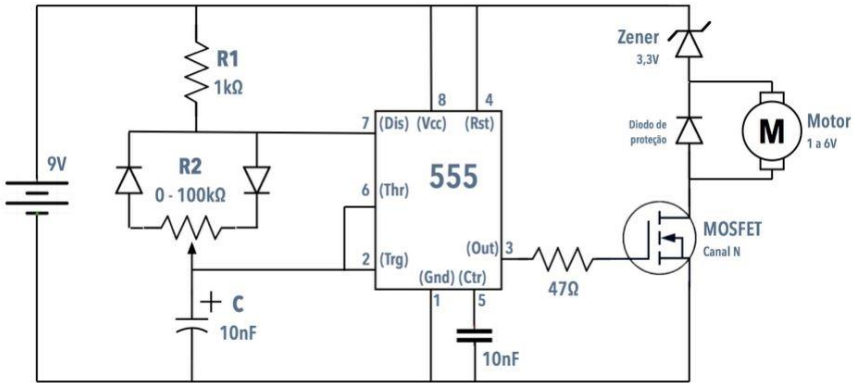
Using Newton's second law, equivalent to that used in the real-size elevator, from the weight variation presented, we observed that the theoretical acceleration of the elevator in this configuration corresponds to 0,229 m/s^2, this is due to the fact that this analysis part only of the variation of the weight that is on the scale.

It is worth mentioning that the data obtained in this experiment are strictly due to the configuration of materials that we used for its construction and execution. Depending on the materials used, values such as the moment of inertia of the pulleys, friction in general, the precision of the balance and other aspects involved, tend to change the result obtained. These systematic errors are natural in physics experimentation and result from simplifications or adaptations of the theoretical model used.

Finally, to make an analogy with the effect of the Weightlessness Principle, we use a speed control circuit (figure 8) of a motor with PWM (Pulse Width Modulation) that uses the following components:

- Um PWM 555;
- A 9V battery;
- A 1kΩ resistor;
- A 47Ω resistor;
- A 10nF electrolytic capacitor;
- A 10nF ceramic capacitor;
- A 2N7000 transistor;
- A variable resistor (potentiometer) of 100kΩ;
- A 5V motor (operates with 1 to 6V);
- A 3.3V and 1W Zener diode (1N4728);
- Three general purpose diodes (1N4148), in parallel with motor and in series with R2.

Figure 8 – Circuit used in the Imponderability Principle experiment



Source: Integrated Circuits (2017).

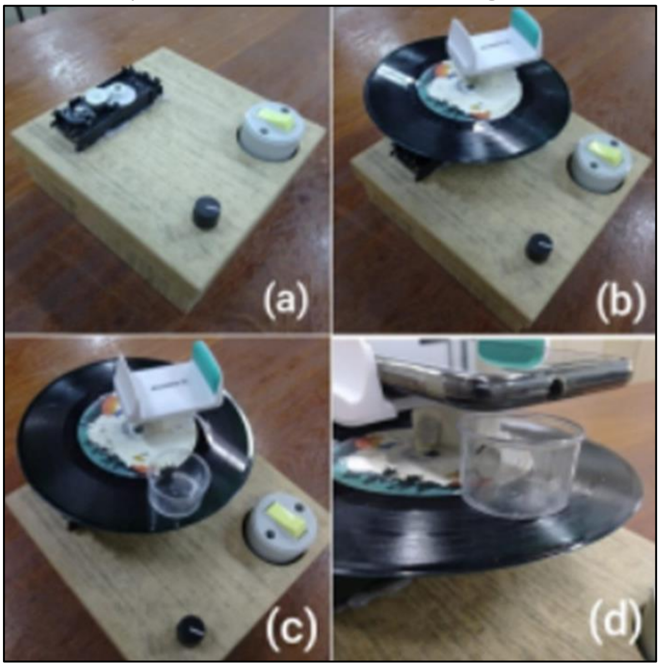
For teachers and enthusiasts who are not very familiar with electronics and who intend to reproduce this experiment, we strongly recommend that you access the electronic address present in the references from where we took this circuit, because there, it was tried to explain the operation of each component of this and many other circuits. The only component that is not included in this circuit and that we added for ease of turning the experiment on and off was a switch.

All these components were found in the laboratory of the Federal Institute of Santa Catarina, Campus of Jaraguá do Sul - Centro, however, they are easily found in electronics stores. The 5V motor is derived from a CD drive found in Campus E-waste, as is its gear set (figure 9a).

For aesthetic reasons, we used a wooden box to serve as the structure of the experiment. A vinyl record was arranged horizontally, coupled to the aforementioned gear set (figure 9b). The purpose of using a variable circuit remote from the need to control the variation of energy provided by the battery to the motor, which will result in the control of the disk rotation, through the potentiometer.

To simulate the effects that the Earth's gravitational force has on the Space Station astronauts, we used above the vinyl disk, a set of two neodymium magnets, in which the first is positioned and fixed in the center of the disk (simulating the Earth) and the second is placed inside a small container placed at an appropriate distance from the center of the disk (the container simulates the Space Station and the magnet simulates the astronauts present inside), so that it still suffers magnetic interaction from the magnet that is in the center (figure 9c). For better visualization, a cell phone holder was also attached above the disk, so that the behavior of the magnet inside the container placed on the periphery of the disk could be recorded (figure 9d). In the next moment, the experiment is set to rotate in order to reach a speed sufficient for the magnet to detach itself from the wall of the container, this behavior being due to the circular movement, resulting in a tendency to go off on a tangent, or commonly reported, to float.

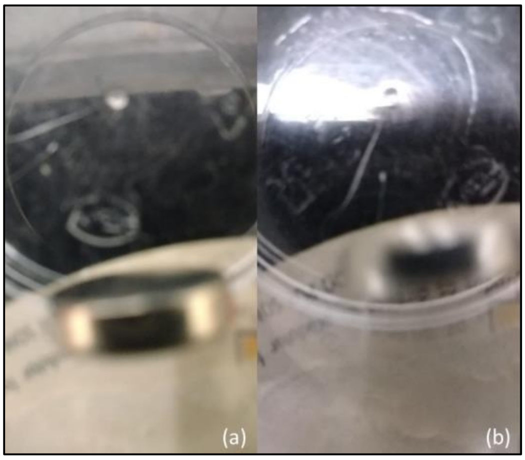
Figure 9 – (a) Gear set in the device; (b) Disc coupled to the gear set; (c) One magnet in the center of the disk and another inside the container at the end of the disk; (d) Cell lined up with the container with the magnet inside



Source: The authors (2022).

Figure 10 shows two printscreens of the video made by the cell phone that was attached to the support on top of the vinyl record, (a) when the record is stopped and (b) when it is rotating at sufficient speed so that the weightlessness effect could be noticeable.

Figure 10 – (a) static magnet, leaning against the wall of the container by the attraction of the magnet inside the disk; (b) magnet lacking Normal Force



Source: The authors (2022).

We provide the electronic address of the video made to capture these printscreens in order to demonstrate the functionality of the experiment (https://www.youtube.com/watch?v=zDWYPq7mTEI&feature=youtu.be&ab_channel=Experimentospmge). Still, in video, it is possible to see that its functionality is not full due to the materials used, resulting in a small unbalance of the rotating disk. Even with the fine control of the rotation speed of the disk, we believe that this is the reason why the magnet, at the end of the video, does not remain in balance and goes off on a tangent. However, for the purpose of demonstrating the effect, the result was satisfactory.

It can be inferred in this case that the experiment is functional by analogously showing a situation in which the normal force decreases until it becomes equal to zero, the latter corresponding to the moment when the magnet moves from its rest position. Several alternative uses are present in this experiment, for example, it is possible to change the distance between the magnets, a factor that immediately changes the rotation speed necessary for the phenomenon to happen, as well as modifying the set of magnets if desired. The possibility of recording the phenomenon and its development while increasing the rotation speed of the experiment is of great value for a clear visualization of the causes and consequences that are related to the physical concept presented.

SCIENCE TEACHING AND EXPERIMENTATION

Noticeably, constructivist theorists have emphasized the importance of the student's prior knowledge in the teaching-learning process. We can also mention, above all, the instruction of the active participation of students in the classroom, emphasizing the importance of understanding in this process (MATTHEWS, 2000) and many other ideas that allowed an improvement of teaching and learning.

The experiments elaborated in this article, for example, can represent a very progressive idea of conceptions, as put by the constructivist theorist Jerome Seymour Bruner, who, in his teaching theory, says that respecting the subject's degree of development and placing the content of so that the student has the possibility to assimilate it, it is possible to teach any subject. In addition, Bruner indicates the existence of gaps that must be filled and the use of discovery as one of the sources for learning, something that can be of great value to teachers who seek experimental practices (BRUNER, 1973a).

Still, the experimentation that is based on the demonstration of concepts, that is, that has the possibility of comparing the data obtained with the existing ones, for Bruner would be "[...] a cycle comprising the formulation of a verification process or attempt, the operation of this process and the comparison of the results with certain criteria [...]" (BRUNER, 1973b, p. 57). In this way, it would be possible for the student through experimentation, in addition to visualizing the concept, trying it and also comparing their results with other expected results, making it possible to bring the content closer to their reality.

However, considering that students' previous ideas play a prominent role in their learning process and also that this takes place through their active involvement, a teaching model was built capable of explaining the transformation of students' conceptions. in scientific concepts, called conceptual change. Perspicaciously, Mortimer (1996) points out that this model is not necessarily the most adequate to represent the learning of scientific concepts and instructs the conceptual profile model, where he states that the understanding of the learning of new concepts does not occur as a replacement for the concepts old ones, as the conceptual change indicates, but when being presented with a new concept, the student starts to live with his previous and new ideas, thus being able, depending on the context, to use the idea that is most convenient for him.

On the subject of this article, we found several researches showing that students do not understand the reason for the astronauts floating on the space station, reporting most of the time a possible lack of gravity (BACCON *et al.*, 2016). These alternative conceptions may indicate that knowledge constructed exclusively by the student, that is, the students being the protagonist of their learning, will not result in scientific knowledge, as the evolutionary model of conceptual change proposes. That is, at some point in their life the student must be introduced to scientific knowledge by someone else and thus the conceptual profile model will present itself in a more adequate way.

For example, when the teacher takes his students to a real elevator to qualitatively demonstrate the effects of its acceleration on the display of a scale, he may notice some surprised comments, some reactions that even inspire us. But when they return to the classroom, no student will spontaneously say that they noticed that "$N = m.(a + g)$". Much less will this phenomenon correlate with the weightlessness effect on astronauts on the Space Station. It is necessary, at some point, to present scientific knowledge to students so that they know how to make such correlations.

Thus, we believe that we, teachers, should have this concern with the teaching of science in experimental practices on a constant basis, even more so when we design as an ideal of teaching-learning approaches that consider the content as a product of science, and above all, relevant to the construction knowledge that generated such understanding. We cannot forget that science as we know it today has more than two thousand years of evolution, and its development has gone through countless controversies and improvements, so we cannot expect a student to develop this knowledge alone.

In the context of experimentation, and especially for the experiments we report on in this article, it is imperative that some ideas about science be presented to students. As they have a very illustrative character, these experiments must be mediated by discussions concerned with how we arrived at these conclusions, otherwise, we could neglect the entire role of formulating hypotheses and problematizations that are part of science, and the learning that could be left with the student is that scientific activity boils down to a method or a script that must be strictly followed, that scientific knowledge is constructed by punctual figures, free from problematizations. Thus, we present below a possible didactic procedure for this sequence of experiments, which aims to teach the proposed contents, as well as some elements of the science development process.

COMMENTATED DIDACTIC PROCEDURE

The suggestion that we propose below considered an ideal scenario where we would have the availability to take the students to an elevator, as well as having all the experiments at our disposal. For this application, we considered four classes of forty-five minutes each, where we seek to direct them with some of the notes made by Moreira and Ostermann (1993) on the teaching of the scientific method.

In addition, we highlight the methodology of the three Pedagogical Moments (3MP) by Delizoicov and Angotti (1994) as the inspired methodological basis for this proposal, whose definition can be understood as: (1st) Initial Problematization, where students are presented with real situations of their daily life so that the teacher can get to know their conceptions; (2nd) Knowledge Organization, where the presentation of scientific knowledge that is necessary for the understanding and problematization of the topic addressed takes place; (3rd) Application of Knowledge, when it is intended to systematically approach the knowledge incorporated by the student. The justification for this methodological adherence to the proposal is due to its connection structure between the student's direct reality and scientific knowledge, which allows extrapolations of phenomena not so frequent in their daily lives.

Class 01

1st moment (30 min.): using a full-size elevator, we can take the students with a scale, which can be either a scale to measure their own weight, or a smaller scale for objects with less mass. In groups of no more than 3 people, you must enter the elevator and position the scale so that it shows on the reader some value for the weight of the object. At this moment, the elevator must be activated so that it goes up and then there is a check of the weight difference when the elevator starts moving, as well as when it stops at its destination. The same can be repeated with the elevator going down.

2nd moment (5 min.): at the end of the experience, the teacher can ask his students about the possible interpretations that they stipulate for the observed phenomenon, generating a debate of hypotheses among students with the teacher's mediation.

3rd moment (10 min.): in this last moment, the teacher can clarify to the students that all these hypotheses raised are important, that a theory formed to describe that phenomenon must be confronted with another, and the one that has greater corroboration, in this case empirical studies, will be able to sustain itself as a current paradigm.

Comment: when we try to illustrate a phenomenon through observation, we have to make it clear to the student that science is not a description of nature, but a model to which we apply and identify possible correlations. In the third moment of this first class, the teacher can explain to the students that a scientific theory does not start from observation, but that this is the one who is biased, full of theories.

Class 02

1st moment (25 min.): introduction to the content Newton's Laws using lecture and dialogue. At this point, concepts related to Newton's three Laws, free-body diagrams and some types of force can be addressed, such as the normal force that will be needed for later experiments.

2nd moment (20 min.): application and connection of the proposed content with the elevator experiment, exemplifying the reason for the weight difference verified in the experiment.

Comment: the first moment of this class refers to the presentation of scientific content, which should be interpreted as being of equal importance to discussions about scientific activity. These can be explored in a very similar way as we brought you at the beginning of this article, as they do not require a very dense physics. In the second moment, the teacher can bring some characteristics about science that are similar to the activity developed in the first class. It can clarify to their students, for example, that the scientist does not have a recipe, a method or a script to operate in science, that they face a constant confrontation of ideas and that these can change depending on the level of evidence they have. Recalling with his students the debate that they had, it is important for the teacher to show that science is a human activity and that it carries all our characteristics.

Class 03

1st moment (20 min.): with the proposal of a miniature elevator experiment, students can be shown the calculation for the difference in weight that will be obtained in the classroom. The experiment can be placed on a scale with an accuracy of 0.1 g and a mass of approximately 100 g on the miniature elevator tray. Masses must be placed on the secondary tray to counterbalance the central tray so that there is movement and then check the differences in measurements obtained.

2nd moment (25 min.): students must calculate, based on Newton's Laws, the apparent weight which is the sum or subtraction between the elevator's acceleration and the acceleration of gravity for the case of the miniature elevator. The teacher can also encourage students to calculate these differences for the case of the real elevator, checking whether, depending on the acceleration or mass used, the weight differences are greater, equal or smaller. For the case of the miniature elevator, you can use a standard mass in the main tray so that everyone does the same calculations. For the second case, they can use their own weight to find the variation and their apparent weight.

Comment: Lecture three can be explored by the teacher to discuss, while the students do their calculations, the predictive potential that science has. That this knowledge, built by us over millennia, provides in contemporary times that we apply it and have an almost non-existent margin of error. And that the development of this knowledge occurs, mainly, by the reformulations of the previous knowledge, showing that science is in constant evolution.

Class 04

1st moment (20 min.): approach to the concept of weightlessness and its application, seeking to establish a correlation with the content of Newton's Laws previously studied. The teacher can, above all, ask his students about what would happen to the observer inside the elevator if the elevator cables were broken, remembering the calculations that his students performed.

2nd moment (15 min.): the teacher can apply the experiment that similarly simulates the principle of weightlessness in the space station, as well as its explanation and functioning, followed by a discussion with the students about the phenomenon. This experiment aims to visualize why there is weightlessness when you are in a circular motion or in an orbit, for example.

3rd moment (10 min.): the teacher can, at the end of this sequence, rescue the hypotheses and theories that his students formulated in the first class about the phenomenon observed in the elevator and show his students that, by having a self-correction system that has been around for a long time, science is the knowledge constructed by us that is closest to our understanding of nature.

Comment: perhaps the greatest asset of scientific knowledge is its own characteristic of sustaining itself in maintaining its own errors. Hypotheses that are not supported by the observations are excluded, generating other hypotheses. The reason to suggest that the teacher rescue the hypotheses and theories of his students in this last moment of the class, does not arise as an intention to demean the plurality of arguments, but rather to demonstrate that in post-truth times, science can be trusted.

The readers can ask themselves about the scenario idealized in this procedure, paying particular attention to the little time that the teacher normally has in his daily life. We agree with that. However, as routinely in physics we idealize a situation so that we can create or apply a model of understanding to what is being observed, we think that perhaps in teaching practices of this kind can be constructive, since this proposed idealization can serve other ramifications. depending on the context that other teachers find themselves in.

Certainly, the activity of taking your students with a scale to the elevator and just showing that butterflies in your stomach is enough to trigger countless discussions about the phenomenon and also about science. However, just the presentation of the experiment that similarly demonstrates the phenomenon on the space station, can encourage students' curiosity about space exploration, astronomy, electrical, and a multitude of contents that can collaborate to scientific enculturation.

In this sense, the teacher's awareness of the importance of appropriating epistemological knowledge becomes imperative. The realizations of experimental practices as a whole must always be concerned with the student's view of science and scientific activity. It is not only possible to bring science closer to the student, but it is necessary. We believe that the teacher has the potential required to carry out the task of showing his students that:

> science is far from a perfect instrument of knowledge. It's just the best we have. [...] One of the reasons for its success is that science has an error correction mechanism built into its very core [...]. Human beings can crave absolute certainty; they can aspire to achieve it; they can pretend, as adherents of certain religions do, that they have attained it. But the history of science - by far the most successful knowledge accessible to humans - teaches that the most we can hope for is a successive improvement of our knowledge, a learning from our mistakes, an asymptotic approach to the Universe, but with the condition that absolute certainty will always elude us (SAGAN, 2006, p.45).

The speeches of the physicist, astronomer and scientific popularizer Carl Sagan, when talking about scientific activity, very well reflect some of the notes of important epistemologists of the last century, such as Kuhn, Popper and Lakatos (CHALMERS; FIKER, 1993) and can serve as an awareness of the importance of bringing science into the classroom.

FINAL CONSIDERATIONS

In this article, we review concepts from Newtonian mechanics applying it to the construction of three experiments: the real-size elevator, the miniature elevator and the space station analogy. Still, we discuss the experimentation in the teaching of physics centered on questions of science content and also on science itself. Finally, we suggest an alternative to the application of these experiments in basic education, proposing discussions that emphasize scientific activity and how scientific knowledge develops.

Experimentation in the teaching of physics faces numerous difficulties ranging from initial teacher training, even to the availability of resources in the teacher's daily life. The experiments developed in this work, for being mostly built with reusable materials, did not require a very large investment. The miniature elevator experiment can be adapted to materials that have greater accessibility for the teacher, such as PET bottles serving as a structure. As for the experiment that served as an analogy to the effect of weightlessness on the space station, electronic components are easily found in any electronics store, with the total value of the experiment not exceeding twenty reals (R$ 20,00). Still, the idea of using the cell phone as an instrument to record the phenomenon can encourage more practices focused on information technologies, and these are important because they are precisely part of the daily lives of many students. For the application stage of this experimental procedure, we think that it should be explored in this way, depending on the context in which the teacher is inserted, because as we put it, it is idealized.

Finally, we demonstrate that even experimental activities can (and we believe that they should) be thought of in the context of the construction of scientific knowledge. It is quite common in physics teaching to see experimental activities focused on obtaining data, formulating graphs and tables, without proper contextualization. We believe that these practices undermine the image that students obtain from science, even more so in the context of experimentation that usually attracts students' attention (and we know how important this is for teaching and learning). We also consider that it is necessary for the teacher to be familiar with the discussions on the epistemology of science, otherwise, he can contribute to the alternative conceptions that students have about science.

POR QUE OS ASTRONAUTAS “FLUTUAM”? A REPRESENTAÇÃO DO PRINCÍPIO DA IMPONDERABILIDADE EM EXPERIMENTOS DESENVOLVIDOS PARA O ENSINO MÉDIO

RESUMO

Muitos estudantes saem do ensino médio sem conseguir identificar saberes básicos de física em seu cotidiano, e quando o fazem, na maioria das vezes, não são capazes de transpor este conhecimento a situações distantes do seu dia-a-dia. Assim, apresentamos nesse trabalho uma proposta de desenvolvimento do conceito de imponderabilidade para o ensino médio, por meio da realização de três experimentos: i) em um elevador real, ii) em um elevador em miniatura, construído para ser utilizado por professores em sala de aula e iii) a construção de um experimento que se utiliza de um circuito eletrônico, que visa demonstrar, de forma análoga, os efeitos da imponderabilidade nos astronautas da Estação Espacial. Para isso, passamos por uma breve revisão do conceito de imponderabilidade e uma discussão sobre a experimentação no ensino de física, abordando a importância destas práticas quando preocupadas com o ensino de ciência e da atividade científica. Por fim, sugerimos um procedimento didático contendo estes experimentos, utilizando-se de algumas asserções sobre o ensino do método científico. Desta forma, consideramos que as atividades experimentais, além de serem elaboradas para a compreensão de um determinado conteúdo, devem ser sempre pensadas, sobretudo, no contexto da construção do conhecimento científico.

PALAVRAS-CHAVE: Experimentação. Ensino de Física. Epistemologia.

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