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# Colombian Prototype of a Spirometer, From Classroom to Practice

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**Abstract**

Design technological tools from basic sciences would be an excellent way for students to learn about Science, Technology, Engineering, and Mathematics (STEM) applications. Nowadays, young people are more connoisseurs of computer tools and gadgets than other generations. They could use those aptitudes with correct stimulation and orientation to generate new knowledge or improve technological applications in developing countries like Colombia. Designing or improving technology starting from basic knowledge and developing cheap technology is essential for the development of a society. We used a case study in this work, due to COVID 19 pandemic, we propose the design and creation of a prototype of a spirometer started from a class activity to put into practice the knowledge acquired in theoretical class and let students observe and implement physics applications. As a result, elemental physics course students achieve testing it on real people and compare it with known results. The students' spirometer prototype was made with inexpensive implements starting with the knowledge learned in the classroom. With it, students tried it on actual patients, letting them get measurable data consistent with known results from the literature. These experiences increased students' interest in science and its applications. This work shows us that applying STEM methodology from basic levels to practical uses could motivate young people to learn and improve their skills in those topics and see science as a way of life.

Keywords: STEM, COVID-19, Spirometer, EPOC.

## INTRODUCTION

Nowadays, advances in the STEM fields (Science, Technology, Engineering, and Mathematics) affect almost all our lives. STEM has raised the need to prepare ourselves in these fields, knowing how to understand and actively participate in social and economic issues and solve trans-disciplinary problems and engineering challenges. (Castro et al., 2020) Scientific and technological innovation is recognized as essential for the growth of developed countries. Implementing STEM education allows developing countries to decrease their dependence on developed countries, increasing their global competitiveness and improving their citizens' standard of living (Caballero, 201) In addition, the health emergency that the world is living through the COVID-19 pandemic showed the importance of information technology and communications (Arenas, 2021).

In 1846, John Hutchinson, an English surgeon, designed the first spirometer before the invention of radiography by Wilhelm Roentgen in 1895 and almost 60 years before the electrocardiogram by Willem Einthoven in 1903. This spirometer was based on a calibrated bell sealed in water to collect the volume of exhaled air. With this essential equipment, he defined the first spirometric parameter for the vital capacity and developed the usual standards based on the measurements made (García & García, 2004; Rivero, 2019; Vázquez & Pérez, 2007) There are also other models of more actual spirometers—for example, the bellows spirometer. Here, the air circuit pushes a bellows, which transmits the volume variation to a guide connected to a paper register. Another type is the pneumotachometer; Inside the mouthpiece, this device incorporates a resistance that makes the pressure before and after exhalation different, and a microprocessor analyzes the difference.

Finally, there is the turbine spirometer, including a small propeller, whose movement is detected by an infrared sensor, to which the information obtained is also analyzed in a microprocessor.(Lata & Saquicela, 2007; Oropeza, 2008). Currently, the portable tabletop spirometer is the most commercial; this instrument includes ultrasound technology and an integrated thermal printer; thanks to the ultrasound, the results obtained in the tests are very accurate and does not need maintenance and calibration; it can accept any gas, regardless of temperature, air pressure or humidity. This spirometer also guarantees total test hygiene thanks to the spirometer nozzles, thus ensuring patient safety.

**Why Colombia?**

Governments must create the conditions that enable all people to live as healthily as possible. These conditions include the guaranteed availability of health services, healthy and safe working conditions, adequate housing, and nutritious food (Olejua & González, 2017) However, in Colombia, the health care system is frequently criticized, with many complaints from citizens about the poor service (Revista Empresarial & Laboral, 2021) The economic and financial crisis engulfing the world also affects health, which depends more and more on the market as it is today's practice. In these circumstances, health turns into a product that becomes more expensive, increasing the price of products dedicated to diagnosing and treating diseases, which generates unequal access to medicine (Álvarez et al., 2016).

The accelerated spread of COVID-19 turned on the alarms about the capacity to respond quickly and efficiently to medical health emergencies, besides the efficiency and quantity of adequate equipment for rapid containment of viruses or bacteria and a correct treatment if there is some contagious. In the case of COVID-19, among all the affectations caused due to those who suffer it, the main ones that stand out are the way it attacks the respiratory system and sequels that in some instances are manifested, particularly in pulmonary disease (Fifield, 2020; Hess, 2021).

Colombia is an emerging country that, like all countries affected by the COVID-19 pandemic, has had to find ways to attend the health needs and requirements of the population, particularly given the great demand for hospital care centers with adequate supplies for the treatment of the symptoms of the virus, especially in those patients with severe respiratory symptoms that require more urgent and thorough control. It is complicated when the demand for these health centers exceeds the number of existing ones. The problem is aggravated when the equipment and instruments to control diseases caused by the virus are not sufficient to meet the needs, given that the costs of many of these types of equipment are usually high (Beltrán, 2013; Medicolsa, 2020).

**From theoretical knowledge in classroom to real practice**

The classroom is an environment conducive to acquiring basic knowledge, keys to understanding, and mastering relevant aspects that can be applied to different situations. However, practice is essential to strengthen said knowledge, mainly if it involves various areas which complement each other to reach a defined objective from a transversal point of view.

As a way to arouse the interest of the students in physics, it was proposed to the students of the physics course to offer and carry out a project framed in the practicality of the area, motivating them to use the knowledge acquired not only in physics course but also in other subjects, such as mathematics and electronics, to be able to scale this knowledge to more everyday and practical situations. Thus, among various projects, the design and implementation of a spirometer prototype were carried out that satisfied the needs for which it was created and whose manufacturing process was simple and economical. Students made a spirometer prototype and obtained two spirometry graphs; the first graph is the spirogram, showing how the air volume passed through time. The second graph shows us the acceleration of this volume. Pulmonary pathologies can be evaluated, monitored, and followed up with these results (Garcia et al., 2013; Vázquez & Pérez, 2007).

The students involved not only acquired and applied knowledge in physics but also knowledge in electronics and programming, which were strengthened with the use of Arduino and appropriate software for the realization of the prototype, whose implementation fundamentals are described below.

The STEM approach has become the protagonist of educational innovation to face the most complex problems of today's world; for this reason, there is a need for the training of new generations of competent teachers and students capable of designing projects where the ways of doing, thinking and talking about science, technology, engineering, and mathematics are integrated. Education must constantly be adjusting to global political, social, and economic changes, hence the initiative of governments worldwide to study the areas related to

STEM to strengthen the skills demanded by the XXI century. This has been an enormous challenge for educators since these areas must be incorporated at all educational levels, teachers must implement teaching strategies that bring together different digital and innovative media to make easier the teaching-learning processes. These strategies are used constantly by different institutions of higher education, especially when it comes to achieving a better approach to teaching mathematics, science, and programming in a didactic and fun way (Baron & Kitri, 2021; Mahecha et al., 2021; Martín & Santaolalla, 2020; Revista de investigación aplicada y experiencias educativas, 2021).

With this new form of theoretical-experimental learning, students' creativity was motivated by expressing original and creative ideas to provide solutions to an essential question; on the other hand, collaboration and effective teamwork were encouraged, and students' critical thinking was also evidenced as they identified, understood and analyzed the current problem, and proposed possible solutions taking into account their application to everyday life.

**Respiratory structure and function**

The respiratory system depends on a highly specialized design for exchanging gasses, primarily oxygen and carbon dioxide, between the atmosphere and the blood. The respiratory system is made up of three components: in the first, there is an air conduction pathway from the external environment to the lung areas and is composed of the nose and the rest of the upper airway to the terminal bronchioles; in the second component there is an area of gas exchange made up mainly of the alveolar-capillary units, and finally, the third part depends on a motor system in charge of executing the respiratory mechanics and which is made up of the rib cage with its bony components and the muscles of respiration, mainly the diaphragm, under the control of the Central Nervous System, with an automatic and a voluntary member (Vázquez & Pérez, 2007).

**Respiratory cycle**

The respiratory cycle is divided into two phases: inspiration and expiration. The first phase allows air to flow into the lungs. The second phase consists of expelling gases from the lungs. The maneuver begins with diaphragmatic contraction, resulting in pleural pressure at rest and then decreases. The alveolar pressure always tends to equalize with the barometric pressure to generate airflow during inspiration (Vázquez & Pérez, 2007, Respiración: MedlinePlus Enciclopedia Médica Illustración, n.d.).

**Resistance and limitation to airflow**

Flows, whether liquid or gaseous, can behave as laminar flows when the streamlines are parallel to the wall of the duct, but when a flow accelerates, the streamlines become disordered forming local eddies giving rise to turbulent flows. On the other hand, the resistance depends mainly on the diameter of the tubes; however, the total resistance of the system is reciprocal to the number of ducts: the airway ducts increase exponentially from the trachea to the alveoli, so the resistance increases progressively towards the trachea and upper airway. The airflow is limited, generating a plateau; even though the pressure increases, the flow no longer increases, and the diameter of the tube mainly determines the limitation to the airflow (Vázquez & Pérez, 2007).

Respiratory function tests are required during respiratory health or disease assessment to support diagnosis, evaluation, and follow-up. Respiratory function can be studied from two components, mechanical and gas exchange. Spirometry contributes to this study and should be a diagnostic tool easily accessible to any physician and used in conjunction with the baumanometer, electrocardiogram, or blood glucose measurement to reduce public health problems throughout the world. (Vázquez & Pérez, 2007)

**Spirometry**

Spirometry is a series of straightforward, non-invasive physiological tests that measure the absolute magnitude of lung capacities and lung volumes, the size of the lungs, and the caliber of the bronchi. Two fundamental types of tests are simple and forced spirometry. We can consider spirometry as the primary pulmonary function test since it allows us to evaluate and thus diagnose and follow-up patients with respiratory diseases such as fibrosis, EPOC (chronic obstructive pulmonary disease), and others. It also allows us to assess the risk of surgical procedures and the therapeutic response to different drugs and epidemiological studies that include respiratory pathologies (Garcia et al., 2013; Miller et al., 2005; Oropeza, 2008; Vázquez & Pérez, 2007).

**Spirometer**

The spirometer is a tiny device used to measure the volume of air expired during a forced breath or inspiration, and it is also used to study lung capacities. Physicians often use it to evaluate the lung capacity of their patients. The objective is to detect any respiratory abnormalities associated with asthma, bronchial problems, chronic obstructive pulmonary disease (COPD), emphysema, pulmonary fibrosis, or even any sickness due to heavy smoking, whether a passive or active smoker (El Tiempo, 2021; Girodmedical, 2011; Reyes, 2018).

**Normal timed spirogram**

Figure 1 shows that the tidal volume (tidal volume or VT) is generated during regular resting respiratory cycles. If the individual breathes in the maximum possible air volume or inspiratory reserve volume (IRV), he reaches his total lung capacity (TLC or CPT).

After that, they perform a forced expiration until they exhale the maximum possible air volume or forced vital capacity (FVC or CVF). The air volume remaining inside the lungs after exhaling the FVC is called the residual volume (RV). The RV added to the expiratory reserve volume (ERV) represents the functional residual capacity (FRC) which is the volume of air that usually exists within the thorax at rest and represents a store of air for gas exchange. Normal timed spirogram (Carvajal & Blanco, 2005; Vázquez & Pérez, 2007).

**Spirometric graphs**

Volume-time and flow-volume graphs are handy for assessing the quality of the maneuver.

**Volume-Time Graph**

Also called a spirogram, Figure 2 plots time in seconds on the horizontal axis (x) and volume in liters on the vertical axis (y). A standard curve shows a rapid steep ascent (A), a transition in book or knee (B), and a plateau describing the duration of the effort.

The proper termination or technical plateau is reached at the end (E) when no volume changes more significant than 25 mL for at least 1 second. In this curve, the FVC, FEV1, FEV6, and the duration of expiratory effort (7 seconds) are easily identified. (Carvajal & Blanco, 2005; Vázquez & Pérez, 2007)

**Flow-Volume Graph**

Figure 3 plots the volume in liters (x-axis) and flow in liters/second (y-axis). In the form of a triangle, the expiratory phase is shown above the horizontal axis and below it the inspiratory phase in the form of a semicircle. A good quality curve shows a very vertical ascent [A], the generation of a maximum flow, peak flow, or PEF [B], a progressive fall inflow [C] as the volume progresses until progressively reaching the zero flow that coincides with the FVC [E].

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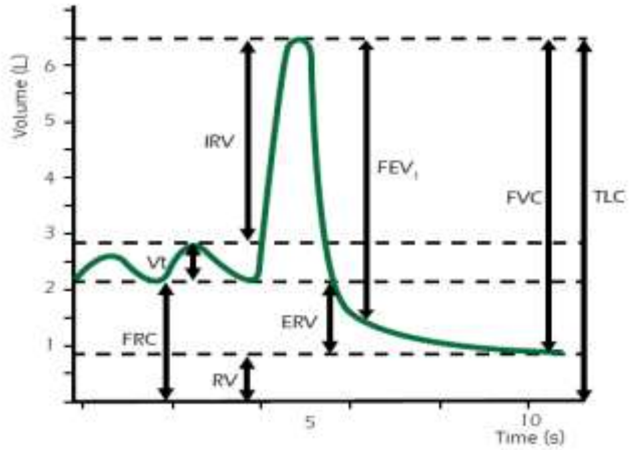


Figure 1: Normal timed spirogram adapted from reference (Vázquez García & Pérez-Padilla, 2007).

The inspiratory phase is semicircular and equals the exhaled volume. FVC and PEF are easily identified in this curve. (Carvajal & Blanco, 2005; Vázquez & Pérez, 2007)

**Main variables measured by spirometry and their definitions.**

- FVC (forced vital capacity): The maximum volume of air exhaled after a full inspiration expressed in liters.
- FEV1 (forced expiratory volume in one second): The importance of air exhaled during the first second of FVC expressed in liters.
- FEV6 (forced expiratory volume in six seconds): The importance of air exhaled at second 6 of FVC. Its use as a surrogate for FVC in-office spirometry.
- FEV1/FEV6: Expressed as a percentage. This ratio is similar to FEV1/FVC to airflow obstruction.
- PEF (peak expiratory flow): Maximum airflow attained with maximum effort, starting from a maximal inspiratory position, expressed in L/s. (Culver, 2012; Gutiérrez et al., 2010; López et al., 2010; Miller et al., 2005; Vázquez & Pérez, 2007)

**Indications for spirometry**

On a superior spirometry test, a medical device is required. Here, the spirometer expands its dimensions by approximately (2.5\times3.0)m$^2$. It is of great importance to know the patient's medical history, such as age, sex, height, and medical history, as these are essential variables for interpreting the results (Garcia et al., 2013; Javier & Orellana, 2013; Casan, 2003; Vázquez & Pérez, 2007)

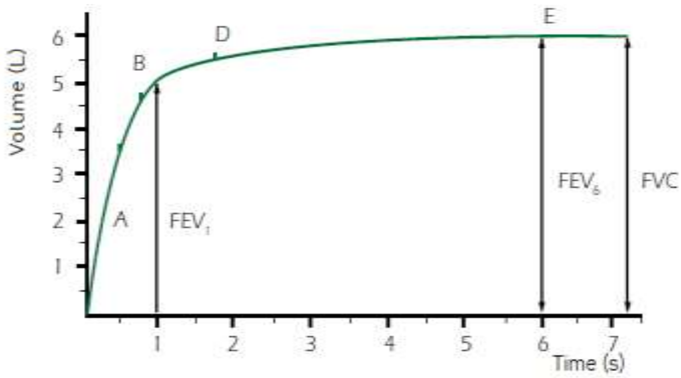


Figure 2: Example of the volume-time curve (VT) adapted from reference (Vázquez García & Pérez-Padilla, 2007)

**Acceptability criteria for a spirometry**

To perform a reasonable interpretation of spirometry is necessary to grade the quality of the same; for this, the spirometry test should always count at least three efforts, or spirometric maneuvers for a better coincidence between results obtained from successive measurements, which involves having the same method, same observer, same instrument, same place, and same condition; repeated over a short period to get good spirometry. On an excellent spirometry test, it is necessary to consider the following. First, determine whether the maneuvers satisfy acceptability criteria such as the beginning of the effort, the duration, and termination of it, also if the maneuvers are free of artifacts such as early termination of the test, cough, variable measures, repeated exhalations, or obstruction in a mouthpiece or leak around it. Second, it is necessary to know if the test is repeatable; this means that two maneuvers should be very similar, and third, evaluate the beginning and end of the maneuver. For this last, should observe the evaluation of the beginning of the spirometric maneuvers in Figure 3, where the VF curve should have a triangular shape with an abrupt and very vertical start, reaching the formation of a vertex, which is generated before 0.1 seconds. It is highly dependent on the effort of the patient. For the finish of the test, we take into account the criterion of termination of expiratory effort, which is established when there is no change in volume more significant than 25 mL for at least one second (Figure 2), as long as the subject has exhaled for at least three seconds. In the case of children under ten years of age, and for at least six seconds in individuals aged ten years or more, the patient is allowed to terminate the maneuver any time they feel any discomfort, especially if there is a feeling of dizziness or near fainting (Vázquez & Pérez, 2007).

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**Mathematical model**

During the operation of a spirometer, we must take into account the power absorbed by the system, which is due to the contribution of the mechanical strength $P_m$ due to the rotation of the propeller, and the electrical power $P_e$ due to the circulation of an electric current through the internal circuit of the system. Thus we define the absorbed power $P_a$ as the sum of the mechanical power and the electrical power.

$$P_a = P_e + P_m. \quad (1)$$

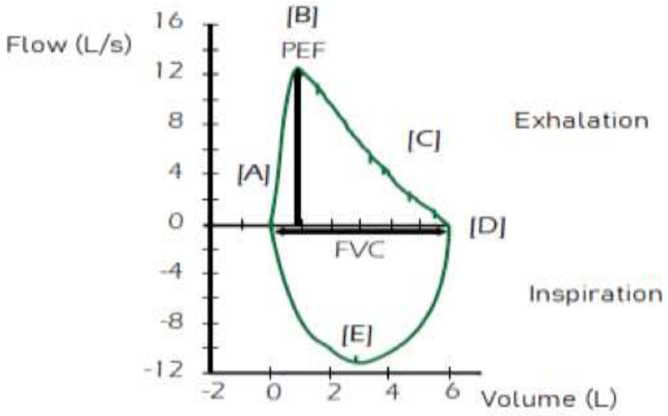


Figure 3: Example of the flow-volume curve (FV) adapted from reference (Vázquez García & Pérez-Padilla, 2007)

Since the electrical power is $i^2R_i$, being $i$ the electric current and $R_i$ the internal resistance; and the absorbed power is equal to $Vi$, where V is the voltage generated across the spirometer, we have:

$$Vi = P_m + i^2R_i, \quad (2)$$

from where

$$V = \frac{P_m}{i} + iR_i \ . \quad (3)$$

Mechanical power is related to the angular velocity ω, and torque T applied to the helix through the relation

$$\mathrm{P}_m = T\omega = T\frac{v}{r}, \quad (4)$$

where r is the radius of gyration. Substituting the equation 4 in 3 we have:

$$V = \frac{T}{ir}v + iR_i \ . \quad (5)$$

On the other hand, the airflow rate is defined as $Q = Av$, where $A$ is the area where the airflow passes through and $v$ its speed. Then

$$V = \frac{T}{ir}\left(\frac{Q}{A}\right) + iR_i. \quad (6)$$

From equation 6 we have:

$$Q = \frac{irA}{T}(V - iR_i), \qquad (7)$$

where $iR_i$ is the initial voltage of the motor denoted as $V_i$

$$Q = \frac{irA}{T}(V - V_i). \qquad (8)$$

Usually, the initial voltage is minimal compared to the system voltage, so that it can be neglected.

$$Q = \frac{irA}{T}V. \qquad (9)$$

Finally, we define a constant that depends on the current values, the helix radius, the tube area, and the torque since these do not vary.

$$\mathrm{K}_E = \frac{irA}{T}, \qquad (10)$$

Obtaining a relationship for the airflow in terms of the voltage generated across the spirometer.

$$Q = K_E V. \qquad (11)$$

It is clear from equation 11 that, for the case of the spirometer, with the generation of voltage starting from a flow of air, we can get a measure of the pulmonary capacity, because this measurement gives us the caudal of air that passes through the spirometer, and so, coming from the patient.

**Spirometer design and development**

Taking into account the proposed objectives, such as cost, data acquisition, and easy handling of the device, a turbine spirometer was implemented, whose construction involved plastic, which serves as a conductor of exhaled air the sensor; this sensor consists of a plastic propeller and a DC motor, plus an acrylic cover as an insulating structure of external currents. Three pieces were needed to position the motor in the center of the device. The cost for the realization of this spirometer was approximately 60.23 USD; with this value, the materials for the parts and the acquisition of data were purchased, not including the laptop computer.

The engine is connected to an Arduino one card, which will circulate the motor's signal and thus process the data obtained. Figure 4, Figure 5, Figure 6, and Figure 7 shows the spirometer prototype developed in this work.

**Operation of data processing by a graphical programming environment software**

The treatment and visualization of data are done in the spirometer, where the information is processed and controlled, being useful for data processing in the software; in this case a graphical programming environment, which provides a robust graphical development environment for the design of engineering applications for data acquisition, measurement analysis, and data presentation; thanks to a programming language without the complexity of other development tools. Inside the virtual instrument, all the necessary processing was performed for the voltage delivered by the sensor as a function of the flow rate due to the expiratory flow. The engine works as a generator and gives us the signal, in this case, would be the voltage produced by rotating the motor shaft with the propeller. The signal reaches in the program through an Arduino card and different cables, is transmitted to the signal comparison, and if the voltage is positive, continuous scanning is performed. When we have the voltage necessary, this goes through some filters to eliminate noises to the movement and thus obtain the best gain of it to get the best results of the prototype. The Spirometer prototype design can be seen in Figure 4, Figure 5, Figure 6, and Figure 7.

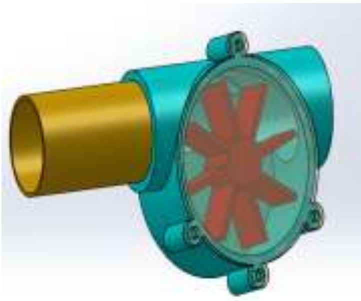

Figure 5 Spirometer assembly in Solid Works

Figure 6. Spirometer prototype

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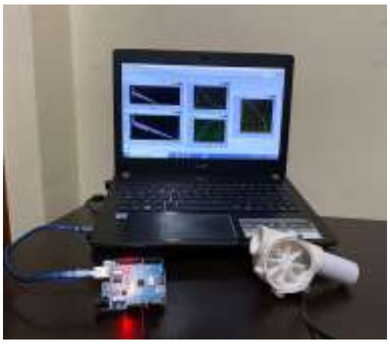

Figure 7. Actual spirometer prototype working connected to an Arduino one card and taking data

We proceed to make the graph of lung volume, which depends on the time, then to integrate the lung volume, we get the lung flow which is still dependent on time and also the flow, and finally joining the two previous graphs, we get the spirometry curve which depends on the volume and lung flow.

**Materials and 3D parts**

The following materials were used for the realization of the assembly of the spirometer; the most notable are the parts in the third dimension; for the completion of these parts was used a solid modeling computer-aided desing program was, which is a 3D CAD design software for modeling parts and assemblies in 3D and 2D drawings.

- **Arduino one board and USB cable.** They were used to receive the signal and transmit it to the computer.
- **DC motor from 3V to 9V**. It is used to generate the signal when moving the propeller to rotate the motor shaft.
- **Spirometer mouthpieces.** They are universal and disposable for personal use and are inserted into the spirometer at each test.
- **Screws and Silicone.** They are used to fasten the spirometer flap.
- **Soldering gun for soldering tin and insulating tape.** It was used to solder the jumper wires to the motor and the tape to better support it.
- **Sandpaper.** It is used to polish the prototype impression.
- **Propeller.** It is a propeller with eight flat blades, made of plastic material, coupled to the motor shaft.
- **Tube and Gate.** The tube is where the airflow will pass through, the hatch will hold the propeller, and at the back, we have support for the motor, also made of plastic.
- **Top.** Made of acrylic, it was used to close the damper and avoid air leaks; it is fastened with screws and a little silicone.

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## RESULTS AND DISCUSSION

### Classroom Method of Design and Research

The quality of education has been paramount in recent years to promote continuous improvement in the education system and a proper formation of future professionals. The basis for this goal is in the classroom. From a perspective very close to reality, education is functional because it generates, through teaching practice, opportunities for those who, at a specific time, lost their interest in learning and growing academically. In this sense, quality will depend on the established parameters to strengthen the environmental conditions that favour the teaching and learning process, many of which complement the teaching and learning method (La Calidad En La Educación Desde El Aula-REVISTA EDURAMA, n.d.)

This project arose from motivation by the physics teacher in the classroom, changing the typical evaluation methodology, and encouraging students to put into practice the knowledge acquired in the physics course and other courses. This form of learning physics showed them the applicability of science in engineering and medicine as it happened in this case. A significant achievement of this work is that due to the practical method for learning physic course, students who participated in this research found a great incentive to continue with research in STEM topics.

Studying the class topics and with more precise knowledge about some specific applicability of physics in medicine, we try to help detect sequelae of lung diseases caused by different sources like smoking cigarettes, pollution, or the current pandemic situation. For that reason, we wanted to reach a manner to design, program, and use a spirometer prototype to get and analyze the data obtained. The most interesting of this project is the combination of different methods and technics from other areas like physics, mathematics, electronics, computation, etc, and how students related them. The students carried out the tests with people of different ages and physiological qualities, obtaining, among others, the curves shown in this work and in accordance with what was described in the bibliography. This last is essential for developing countries because it would let them get technological instruments at a low cost. The spirometry graphics from the spirometry test can be seen in Figure 8, Figure 9, Figure 10, Figure 11, and Figure 12.

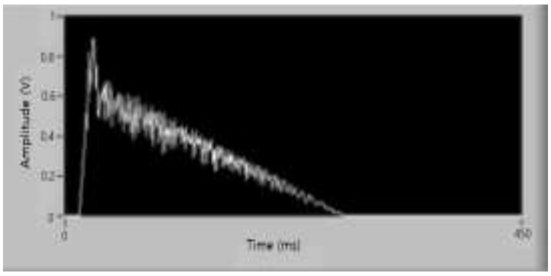


Figure 8. Continuous scanning

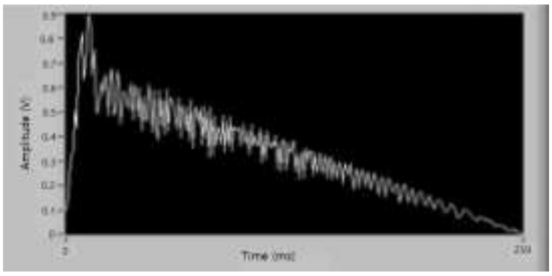


Figure 9. Pulmonary airflow

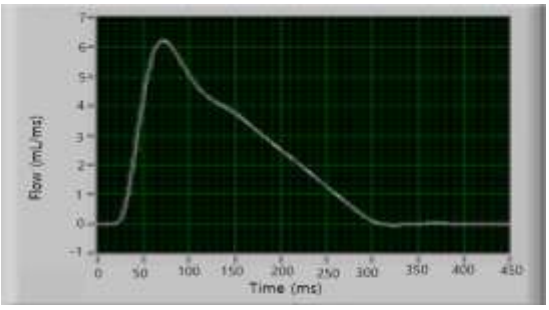


Figure 10. Signal comparison

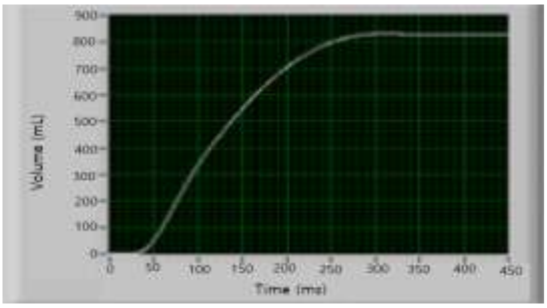


Figure 11. Pulmonary volume

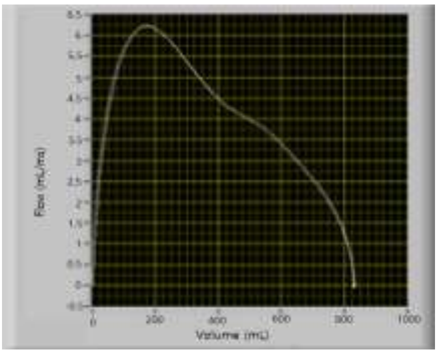


Figure 12. Spirometry curve

On the other hand, from an educational perspective, designing and making the spirometer from cero to get a practical and functional prototype managed to generate in the students more interest in science and that they want to keep working on STEM topics.

**Testing performed**

To evaluate the efficiency of the developed prototype, spirometric tests were performed on patients with different physical conditions and medical backgrounds and the results compared with the theoretical curves predicted by the literature (Vázquez García & Pérez-Padilla, 2007). In Figure 8, Figure 9, Figure 10, Figure 11, and Figure 12, we can observe the graphs obtained with the prototype spirometer from the spirometric test performed on a 37-year-old female patient, height 1.47 m, healthy non-smoker, and with no history of pulmonary diseases. Those tests were performed on other patients of different ages and physical characteristics, obtaining similar results. The spirometry graphics comparison from the

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experimental graphs were obtained with the spirometer compared with the theoretical curves can be seen in Figure 13, Figure, 14, Figure 15, and Figure 16.

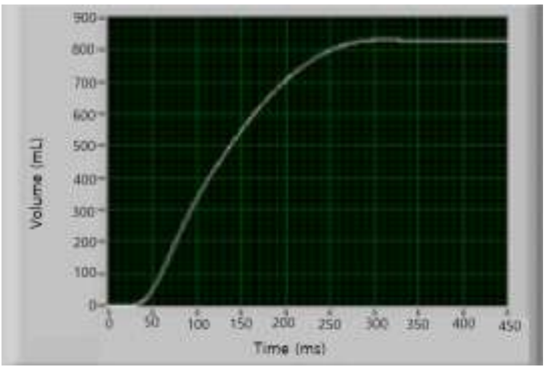


Figure 13 Pulmonary volume was obtained with the spirometer adapted from reference (Vázquez García & Pérez-Padilla, 2007).

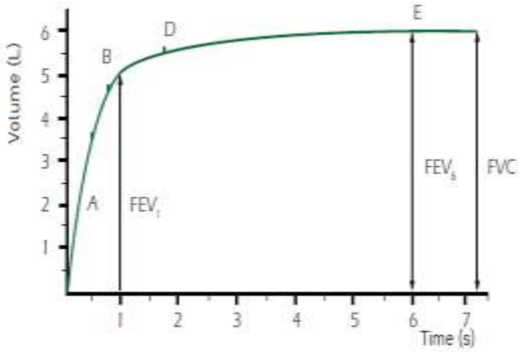


Figure 14. Theoretical lung volume

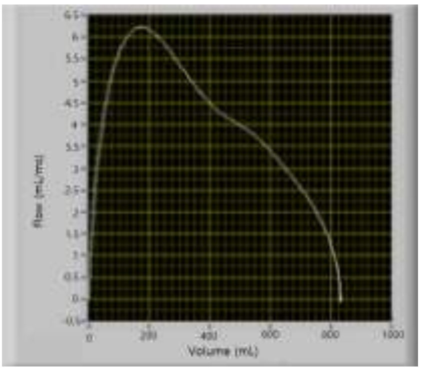


Figure 15. Spirometry curve obtained with the spirometer

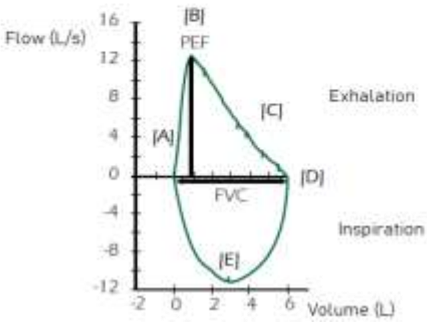


Figure 16 Spirometry theoretical curve adapted from reference (Vázquez García & Pérez-Padilla,

Figure 6 compares the results of the spirometric tests obtained with the prototype proposed in this work and the known theoretical graphs. We can observe the acceptability criteria mentioned in theory and the information provided by the individual who took the test. For that, we can affirm that the pattern of the graphs is very similar. In Figure 6-a, we notice that the volume rises considerably in the first second and then is maintained, which indicates that there is no obstruction or restriction in the lungs, likewise in Figure 6-b, we observe at the beginning of the test that it rises very quickly forming a triangular shape and reaching the vertex before the first second, this indicates that there is no slight obstruction to airflow, with the above considerations we can affirm that the volume of the lungs is adequate for the age, sex and height of the individual evaluated, in addition to corroborating that his respiratory system is in proper condition for a healthy person. In this sense, for a country like Colombia to have the possibility to design and make technologies more economical than their commercial equivalents will allow increased access to this class of treatment to people with low economic conditions. This work shows that using unexpensive and easy acquiring tools lets carry out this objective.

This project, which startup from a practical project in a physics class, lets students learn, practice, design, and make a functional device with immediate applications in medicine and learn about topics like physics, programming, electronics, and medicine. Besides, students have the possibility of developing a real and practic project in which they had an important role and in which they could apply their knowledge on STEM subjects, increase their interest in those topics, and improve their skills in science and technology; and also I believe that it would motivate other women to learn and venture into STEM areas.

## CONCLUSION

The application of STEM knowledge in developing middle-income countries like Colombia is a crucial way to improve the conditions of life of people because applying technological and scientific knowledge derived from STEM subjects lets us solve problems get from everyday life. Practical teaching methodologies allow students to the incursion into physic applications and, in a certain way, contribute to the technological advances to solve immediate problems, increasing students' interest in science and engineering.

Beginning from experimental work in the classroom, students of introductory physic courses can understand the theoretical knowledge acquired in physics class to see the importance of basic science and its applications in quotidian life and improve their scientific skills. Actual applications of science encourage students' interest in following the scientific profession.

In a particular case, like the medical field, especially in pneumology, the implementation of techniques to design and make medical equipment at a low cost but with the same efficiencies and functional warranties that others more expensive would be a reasonable manner to improve the living conditions of patients who need this equipment but do not the conditions to access to it. For these reasons, the design and implementation of a spirometer prototype with economic implements, conducting tests on actual persons, and having good results in accordance with those obtained with a commercial spirometer, was not only a practical manner of solving the immediate necessities but also increased the interest of students by science and engineering.

With the implementation of more economical medical instruments, health professionals would easily acquire a low-cost spirometer for clinics and hospitals, favoring the spirometry treatment in countries like Colombia to prevent diseases of respiratory pathologies.

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