What did first-year students of physics learn previously about experiments that show existence of atmospheric pressure?

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Abstract

Experiments related to the existence and the characteristics of atmospheric pressure are among the most important ones in the history of physics. As many old-time scientists had wrong explanations of phenomena related to atmospheric pressure, there is no wonder that today's pupils and students reveal similar conceptual difficulties and ideas (for example, the conception of acting vacuum). Classroom demonstrations dealing with air pressure are actually very present in Google documents and in YouTube videos. Critical-minded and creative physics teachers might use them to help students overcome mentioned conceptual difficulties. The aim of this small-scale and qualitative exploration study was to find out which experiments and demonstrations, showing existence of atmospheric pressure, are known from previous schooling to a group of 29 first-year students of physics. The most alarming finding is that 14 students (almost 50 %) said they did not see or couldn't remember any experiment or demonstration related to atmospheric pressure. Only three students were able to describe and explain a feasible classroom demonstration of the existence of atmospheric pressure. Three more students gave rather poor description (and explanation) of the experiment of Torricelli. Other students mentioned a lightly related or a totally unrelated experiments or demonstrations. At the end, some implications of these disappointing results for physics learning and teaching are briefly discussed.

Keywords: Students' knowledge about atmospheric pressure, Students' physics learning from demonstrations, Didactical contract.

Resumen

Los experimentos relacionados con la existencia y las características de la presión atmosférica se encuentran entre los más importantes en la historia de la física. Como muchos científicos antiguos tenían explicaciones erróneas de fenómenos relacionados con la presión atmosférica, no es de extrañar que los alumnos y estudiantes de hoy en día revelen dificultades e ideas conceptuales similares (por ejemplo, la concepción del vacío actuante). Las demostraciones en el aula sobre la presión del aire están realmente presentes en los documentos de Google y en los videos de YouTube. Los profesores de física con mentalidad crítica y creativa pueden usarlos para ayudar a los estudiantes a superar las dificultades conceptuales mencionadas. El objetivo de este estudio exploratorio de pequeña escala y cualitativo fue descubrir qué experimentos y demostraciones, que muestran la existencia de presión atmosférica, se conocen desde la escolaridad anterior a un grupo de 29 estudiantes de física de primer año. El hallazgo más alarmante es que 14 estudiantes (casi el 50%) dijeron que no vieron o no recordaron ningún experimento o demostración relacionada con la presión atmosférica. Solo tres estudiantes pudieron describir y explicar una demostración factible en el aula de la existencia de presión atmosférica. Tres estudiantes más dieron una descripción bastante pobre (y explicación) del experimento de Torricelli. Otros estudiantes mencionaron experimentos o demostraciones poco relacionadas o totalmente independientes. Al final, se discuten brevemente algunas implicaciones de estos resultados decepcionantes para el aprendizaje y la enseñanza de la física.

Palabras clave: Conocimiento de los estudiantes sobre la presión atmosférica, física de los estudiantes aprendiendo de las demostraciones, contrato didáctico.

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I. INTRODUCTION

Far-reaching scientific truths might be quite surprising for common-sense thinking, constructed uncritically on sensorial and practical experiences. A good example is daily rotational motion of the Earth.

In his book "Dialogue Concerning the Two Chief World Systems" [1], Galileo discussed carefully many "obvious" objections formulated by the opponents of the Earth's rotational motion. They were spoken out by Simplicio, who was bringing the core of Aristotle's philosophy "… sensible experiments… ought to be finally preferred… above anything that can be supplied by human argument" [1, p. 46].

If the equatorial parts of the Earth move at an impressive speed (of 1,667 km/h o 463 m/s), then, according to believers in the word system with a static Earth in the center, some phenomena must happen: a strong wind due to its motion through the air, a visible counter displacement of birds and clouds that don't move with the Earth and everything would spin off the ground due to action of a huge centrifugal force.

As these phenomena were not observable, then "sensible experiments" show that the Earth doesn't perform its diurnal motion. Galileo was able to show why the absence of two first supposed phenomena isn't valid scientific proof. Why the third supposed phenomenon doesn't occur was possible to understand only later, when physics got precise quantitative knowledge about values of gravitational and centrifugal forces.

Other dialogical points were related to motion of canon ball in free fall from a high tower or ranges of canon shots toward East and West. According to Simplicio, if the Earth is moving, the canon ball can't follow a vertical path and shots toward East and West must have different ranges.

Again, as "sensible experiments" show that canon ball falls vertically and that the ranges of shots are the same, it seems "obvious" that the idea of diurnal Earth's motion must be rejected. Nevertheless, Galileo could demonstrate that these "observational facts" are compatible with the idea of a moving Earth.

This important historic episodes show that the same observations can be interpreted in different and quite opposite ways (moving vs. static Earth). In physics teaching, plurality of possible explanations of a phenomenon should be put at the center of students' learning because students have their initial world knowledge constructed in an unscientific way. In other words, in everyday world students commonly don't put their explanatory ideas about experienced physical phenomena on experimental tests, by exploring their predictive power when these phenomena are modified or moved into another context.

Unfortunately, in traditional physics teaching students are not supposed to explore their explanatory ideas. Instead they receive, from a physics textbooks or teachers, scientific explanations, sometimes superficial and incomplete, as something self-evident and, consequently, something that is not in need to be put on any experimental exploration of its veracity.

In physics textbooks of today, big scientific ideas, like "all substances are made of particles" or "all electric phenomena are due to the motion of electrons", are presented as dogmatic truths, without mentioning numerous fierce discussions and chains of creative experiments that were necessary in accepting them by scientific communities.

II. HISTORIC EXPERIMENTS RELATED TO ATMOSPHERIC PRESSURE

During many centuries, surprisingly unnatural behavior of water in siphons, syringes, clepsydras and pumps was explained by the conception of "abhorrence of a vacuum", developed by Aristotle. In his philosophy, nothingness is an absurd idea. Among other arguments, one is that vacuum can't exist because bodies would move in an empty space with infinite velocity.

In that conception, nature and its parts behave in such a way that it is impossible to create a vacuum (a matter-free space). For example, in a siphon water unnaturally goes up in short part of the tube in order to prevent creation of a vacuum that would be formed when water flows out of the longer tube.

Torricelli carried out well known crucial experiment with mercury to show that it was possible to produce vacuum "without effort and without resistance on the part of Nature".

Torricelli explained the height of the mercury in his experiment (about 76 cm) as caused by the pressing action of the atmosphere on the mercury in container in which the open end of the tube was immersed. In such a way, the height of the mercury was a measure of atmospheric pressure.

Torricelli and Pascal wrongly "explained" the atmospheric pressure as a consequence of the "weight of atmosphere". That "explanation" showed certain predictive power because successfully predicted that going up in atmosphere, with less air above, the height of the mercury column caused by smaller weight should be shorter. Pascal's brother-in-law Florin Périer confirmed that prediction by in the year 1648, performing barometric pressure measurements on two different heights (one at the base and one at the top of Puy-de-Dôme, one of the highest mountains in central France).

Physically correct explanation of the nature of atmospheric pressure connects its local value not with the weight of the air above but with its local density.

Invention of vacuum pumps made possible to show amazing effects of the existence of atmospheric pressure. Magdenburg's mayor Otto von Guericke, performed in 1656 the first public spectacular demonstration of the action of atmospheric air. (Fig. 1).

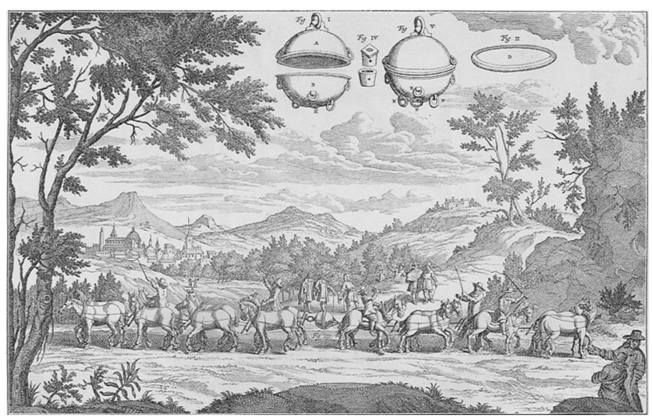

FIGURE 1. First public demonstration of the action of atmospheric air, performed by Otto von Guericke.

As it can be seen, 16 horses were unable to separate two copper hemispheres in whose interior a low-pressure space has been established by a vacuum pump.

When dealing with historic experiments in physics teaching, it is important to avoid superficial descriptions and incomplete explanations. Namely, it is known from research, that students are prone to get wrong understanding about physics involved in Torricelli and Pascal experiments [2, 3]. West [4] recently published an informative account of the experiments carried out by Torricelli, Pascal and von

Guericke that might be useful in teaching about these experiments.

III. TODAY'S DEMONSTRATIONS RELATED TO ATMOSPHERIC PRESSURE

In the time of von Guericke, a vacuum pump was a necessary item in a convincing demonstration the existence of atmospheric pressure. As such devices were at the cutting edge of technology, only very few people could have them and even less people were in position to use them to show to general public such an incredible force of surrounding air.

After 350 years, due mainly to creativity of many generations of physics and science teachers, there are today numerous demonstrations or "classroom experiments" related to visible effects of atmospheric pressure. The basic idea of these demonstrations is to create a low-pressure space, by different materials and procedures, and let the atmospheric pressure do the rest. Their attractive feature is the fact that, in many cases, needed materials are cheap and can be found easily (balloons, syringes, peeled hard-boiled eggs, plastic and glass bottle, cans, …).

By the year 1950, 22 different demonstrations of atmospheric pressure were proposed as suitable for science classroom [5]. The pedagogical objectives of these demonstrations were "to show that (1) there is no such thing as suction, (2) the atmosphere exerts pressure, and (3) this pressure is exerted in all directions." These objectives, as it will be seen later, are still valid and important in today science and physics teaching.

It is interesting to note that the ninth of these 22 demonstrations, breaking a ruler covered by a newspaper with the "help" of atmospheric pressure, seems to be controversial. For some teachers, it shows clearly the presence and action of atmospheric pressure on the newspaper [6], while, for others, this demonstration has nothing to do with the pressure of air [7].

Due to development of technology, some important historic experiments, like one performed by Boyle in which a semi-inflated lamb's bladder increased its volume in vacuum machine, can be carried out now easily with a kitchen vacuum container and a balloon [8].

To get a rough idea of a great number of demonstrations, one can enter search term "demonstration of atmospheric pressure" on Google. She or he would get almost 100,000 results!

The site YouTube shows more than 46,000 videos that mention "atmospheric pressure" and many of them are related to demonstrations of effects caused by atmospheric pressure.

Surprisingly, a search with "demonstration of atmospheric pressure" in academic publications gives only 53 hits. It means that today, students are more likely to consult a non-academic publication or video in searching for atmospheric pressure demonstrations. Such learning resources, missing a quality control common in academic production, might sometimes mislead students.

One of the most popular videos, seen by more than 4'500,000 times, is named "55 gallon steel drum can crash" (https://www.youtube.com/watch?v=JsoE4F2Pb20). In this spectacular demonstration, a steel barrel, sealed after being filled with water vapor, was put into a container with icy water (Fig. 2). When the water vapor condenses, the inside pressure becomes very low and the barrel, unable to resist much bigger atmospheric pressure, is loudly crushed (Fig. 3).

FIGURE 2. Sealed steel barrel filled with water vapor in icy water.

FIGURE 3. Steel barrel becomes crushed when the its interior pressure of water vapor becomes very small due to condensation.

Crushing a steel barrel is an amplified version of a very popular classroom demonstration in which a soda or cola can is crushed in a similar manner [9]. This demonstration is still revisited in searching for new learning opportunities for students [10, 11].

The video "Exploring Air & Air Pressure", produced by "Fun science demos" [12], starts with a challenging practical puzzle: how did I get the water-filled balloon in this bottle? (Fig. 4)

In a step-by-step fashion with hints, Jared (the narrator in the video) shows and explains that the solution to the puzzle is a well-known situation in which is possible, due to atmospheric pressure, to have a balloon "inflated" in a bottle with a hole, even when the balloon's mouth is left open [13].

FIGURE 4. How to put a water-filled balloon in a bottle?

While Jared follows scripts of traditional teaching, posing basically rhetorical questions he answers himself, Lee [14] proposed and implemented a better pedagogical approach, giving his students a real classroom chance to creatively solve another practical puzzle "how to put a peeled boiled egg into a bottle?" Students firstly have shown a surprising range of interesting proposals, but almost all of them didn't involve the idea to use a pressure differences between inside and outside air. After seeing three different demonstrations showing existence and actions of atmospheric pressure, they proposals improved significantly. It means that experiences with a concept can help students apply it creatively in solving practical problems ("puzzles") in new contexts.

Taking into account huge diversity and popularity of demonstrations related to atmospheric pressure, it is interesting to explore what did first-year physics students learn about these demonstrations and experiments in their previous schooling.

In addition, it was hopefully expected to get indirectly some initial insight into whether some these demonstrations were productively used to improve pre-university students' conceptual learning of atmospheric pressure and various physical phenomena that it is directly relate with.

IV. SCHOOL LEARNING ABOUT PHENOMENA RELATED TO AIR PRESSURE

Many researchers have explored pupils' and students' alternative conceptual frameworks they have or invent to describe, explaing and predict different classes of phenomena related to air pressure [15, 16, 17, 18].

One of the most known alternative conceptual framework is that of "active vacuum", similar to a "scintific idea" launched to challenge Torricelli's explanation of his experiment. For example, when explaing upward liquid motion in drinking straw, students say that the mouth, by inhaling air from the straw, creats a vacuum that sucks the water up.

Basca and Grotzer [19] sumarized the essence of these conceptual frameworks, that obstaculize their learning of scientific conceptions, in the following way:

1. Students reason using obvious variable rather than considering nonobvious variable when determining the causes of pressure-related events.
2. Students reason linearly rather than systematically when thinking about pressure.
3. Students often think of pressure as a directional quantity, pushing down on things, rather than existing in an omni-directional fashion.
4. Students often use the terms pressure and force interchangeably.

For example, when pupils are asked why a child is unable to inflate a balloon inside a bottle, for many of them the first explanation is that the child is too weak. When this explanation is challenged, by showing that even an adult person is unable to inflate the balloon in the bottle, they give causal role to another visible variable: the strength of the balloon. It is quite hard and time-consuming to get them to construct explanation based on the pressure of the air trapped between the balloon and the bottle's wall (nonobvious or invisible variable).

A similar synthesis of students difficulties in understanding air pressure and related physical processes, when they are supposed to think in terms of an elementary molecular-kinetic theory, was given by She [20]:

> "Air pressure involves the understanding of invisible and abstract attributes because air exerts pressure and is made of tiny particles (molecules) that are constantly moving (invisible and process attributes). For air pressure, students need to understand that air particles (invisible attribute) exert pressure on all sides of the system, including whatever is inside the system (abstract and process attributes)."

Another complication in learning is the fact that young pupils don't think causally by using common physical concepts but are prone to generate analogical explanations of phenomena related to air pressure and change them in an arbitrary way during collaborative peer discussions [21].

Conceptual-change teaching is commonly used to help student overcome their unproductive ideas related to air pressure [22]. A research-based example of teaching design that takes into account complexity of thinking about invisible causal agent to give students multiple opportunities to go from linear to relational causality in understanding physical phenomena related to air pressure is given in the document "*Causal patterns in air pressure phenomena. Lessons to infuse into pressure units to enable deeper understanding*". Belinda Basca and Tina Grotzer, from the Harvard University, created that excellent learning sequence in the "Project Zero" [23].

Although conceptual-change teaching is a step in right direction, the success isn't assured. For some students a pressure-related demonstration (peeled hard-boiled egg enters into a bottle due atmospheric pressure that is bigger than interior pressure) reinforces previous understanding [24]. Very likely, these students utilize their prior knowledge and experiences to construct the purpose and meaning of the demonstration and, consequently, are not sufficiently challenged by observing the demonstration or by the social interactions that occurred.

V. THE AIM, METHODOLOGY AND SAMPLE OF THIS STUDY

This is a small-scale, initial qualitative study whose aim to explore type, extension and origin of specific experimental knowledge about air pressure phenomena that first-year physics students were able to learn in previous formal (or informal) education.

The group of 29 physics students participated in the study during a regular session of a first-semester course "Development of Complex Thinking Skills" (Autumn 2017). Their paper-and-pencil task was:

> "Some persons don't believe in the existence of atmospheric pressure. One of their arguments is that the air doesn't have weight and, consequently is unable to exert pressure. Other argument is that something that we can't feel is inexistent.
>
> By which experiment might you demonstrate that the atmospheric pressure really exists?
>
> Provide (1) a scheme of the experiment, (2) a description of the procedure and its physical reason and (3) indicate how you learned about that experiment."

The time students had for this remembering and writing task was 20 minutes.

VI. THE RESULTS OF THIS STUDY

A. Students haven't seen o can't remember an experiment or demonstration

The most alarming result of this study is that 14 students (almost 50 % of the total number) declared that they haven't seen or can't remember any experiment or demonstration showing the existence of atmospheric pressures. These students can be divided in two groups.

In the first group, four students only provided their declarations:

"I never had an opportunity to observe an experiment that demonstrates the existence of atmospheric pressure, neither in textbooks nor in classroom."

"I have never seen a demonstration."

"I have never had a contact with an experiment which demonstrates it."

"I don't know any experiment of that type."

To the second group belong ten students who, although declared that they have never seen or can't remember a demonstration in question, provide a description of an experiment. Two of these students describe how to show that air has weight.

"Put on a balance two containers, one full of air and other empty."

"*Weigh two similar containers, one empty and the other filled with air. Empty container would weigh less and consequently, the air has weight*."

It is likely that these students think that demonstrating air's weight is, at the same time, the evidence that atmospheric pressure exists. This kind thinking might have been caused by the formulation of the task (see above).

One student goes even further by thinking that the essence of task was to demonstrate very existence of air:

"Inflate a balloon. If air doesn't exist, it would be impossible."

Remaining seven students provided either a description of an unrelated experiment or an unclear experimental proposal. Here come four examples of mentioned unrelated experiments (or, better said, physical events):

"Hot water floats on cold water."

"Air, compressed in a closed syringe, expands when extra external pressure is removed."

"A balloon filled with helium goes up and the one with air gets to the ground."

"Inflate a plastic bag, tie it up and make it explode."

How to interpret these students' answers?

One possibility is to suppose that students thought that the mentioned physical event are somehow related or caused by atmospheric pressure.

The other, maybe more likely, possibility is to take these answers as particular reflections of "classroom culture" in which teacher's declared or inferred grading practice leads students to believe that on exams is much better to write anything than nothing. Namely, it is known from research that the system of students' beliefs and expectations determine greatly their classroom thinking and actions in physics learning [25].

There were 15 students who didn't declare that they haven't seen or can't remember experiment or demonstration. In what follows, their answers are presented and commented.

B. Three examples of acceptable experiments

Only three students describe an acceptable experiment related to visible action of atmospheric pressure, citing sources of their knowledge.

The first is well known demonstration with a glass full of water, found in many textbooks and science books for kid. The glass is covered by a postal and turned upside down. The postal card stays at its place and the water doesn't flow out.

A correct physical reason of it, given the by the student, is: *"Air pressure is stronger than pressure exerted by water."*

The student says that the source was video seen at Facebook.

The second is less known phenomenon that water does not flow out of a bottle with a hole, if the mouth of the bottle is tapped. The students correctly explains the physics involved in the situation:

"Atmospheric pressure is bigger than hydrostatic pressure of water in the bottle."

The student cites *"a high-school teacher"* as the source of the demonstration, although it is unclear whether it happened in or out of classroom.

The third example is the demonstration in which a candle with flame is placed in a plate with water. The candle is covered with a glass. After the flame goes out, the water rises in the glass.

The student was not sure why this happens. It is understandable, because the event was learned at an age of 10 years, "as a part of a game".

It is important to note, that only one of three remembered demonstrations was eventually learned in the classroom. Two others were learned in out-of-school settings.

C. A possibly related experiment

A student describes a demonstration that is not commonly known as one showing an action or existence of atmospheric pressure. Nevertheless, one author [5] considered it as such.

Here comes student's description, slightly edited. The figures are numbered and figures' texts are added.

"It could be carried out with an inflated balloon (and a container) (Fig. 5)

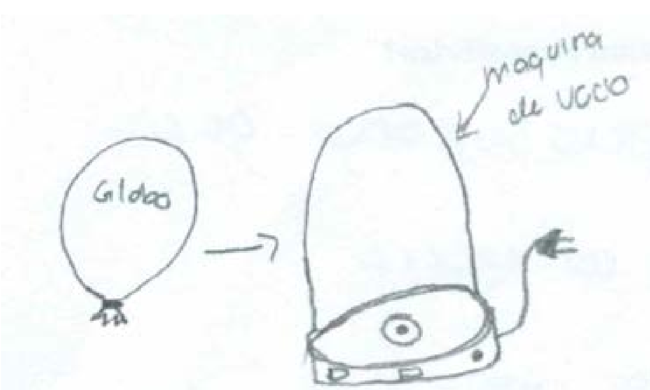

FIGURE 5. The balloon and a container. On the drawing, the container is called "maquina de vacío" what Spanish expression for "vacuum machine".

It is introduced in a container, sealed to vacuum (Fig. 6).

FIGURE 6. The balloon and in the container, sealed to vacuum.

After that, we take out the air from the container. What the balloon does is to expand little by little until it explodes (Fig. 7).

FIGURE 7. The balloon explodes (In Spanish "globo explota").

This means that, due to absence of oxygen, the atmospheric pressure is much stronger."

The student fails to give a correct physical reason why the balloon exploded. Instead, an arbitrary affirmation about the relation between the absence of oxygen and the strength of atmospheric pressure is given.

The student doesn't mention a source of his knowledge source mentioned, but it is unlikely that this demonstration was seen in a classroom. More likely sources might be a physics textbook or a YouTube video.

D. Three students describe the experiment of Torricelli

Although the task asked for an experiment that students might carry out themselves, three students describe the experiment of Torricelli (without mentioning his name). All of them include a schematic drawing of the iconic experiment.

Here comes the description of the first student. The figure is numbered and the figure's text is added.

"Procedure Simply expose the barometer to the outdoor to see the

level of mercury".

Reason By exposing the rudimentary barometer, the mercury in its interior *goes up* to a certain height due to the atmospheric pressure that exists at this level.

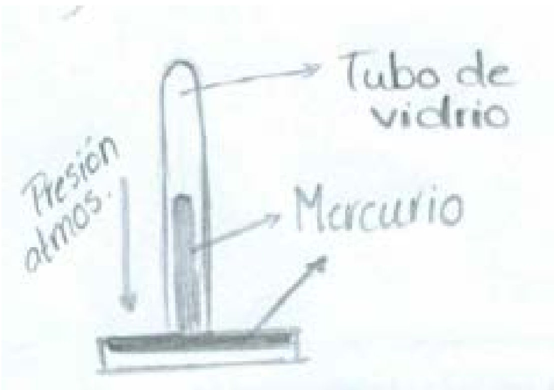

FIGURE 8. A schematic presentation of Torricelli experiment (Presión atmos. = atmospheric pressure; Tubo de vidrio = glass tube; Mercurio = mercury).

This student has a clear idea that the height of mercury depends on location regarding sea level. For example, at the top of a mountain the Hg should be below the level recorded at the sea level, because to a higher location (corresponds) a smaller pressure.

Nevertheless, the student wrongly says that the mercury goes up in the tube instead of flowing out of initially *full tube*. The student tells a short story about the source of reported knowledge:

"I never saw a demonstration, but I had to expose one in third grade of high school. I read about it on Internet and in a physics textbook."

The second student gives the following account (the figure is numbered and the figure's text is added):

"A container is filled with mercury and a test tube is placed in with the open part downward. Due to atmospheric pressure, the mercury *goes up* a certain height inside the tube.

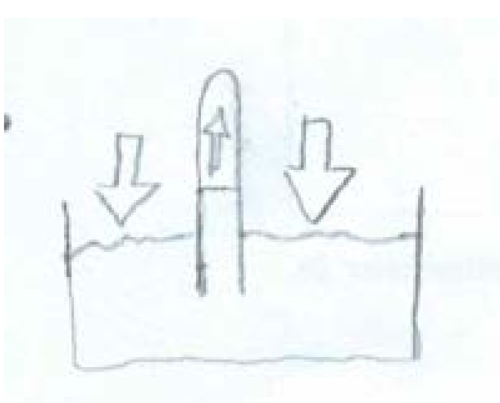

FIGURE 9. Another schematic presentation of the Torricelli experiment.

The height of the mercury indicates local atmospheric pressure."

The student doesn't mention a source of the knowledge.

As the first one, this student also thinks that the mercury should flow into the tube from below. This idea is not only presented verbally by "goes up", but it is enhanced visually a an upward arrow (see Figure 9).

A very defective recall of the Torricelli experiment was given by the third student. With the figure numbered and the figure's text added, the recall is as follows:

"A container with mercury is used. A metal stick is introduced into the mercury.

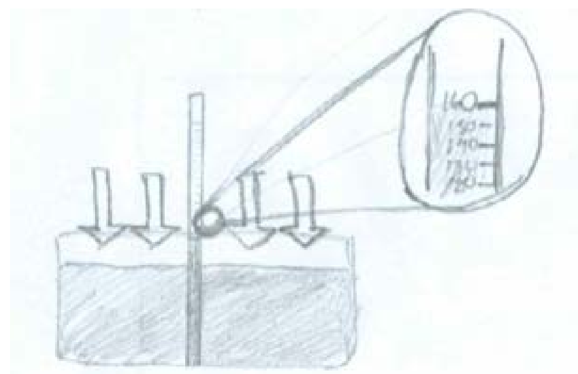

FIGURE 10. Another schematic presentation of Torricelli experiment with a zoom.

Atmospheric pressure at the sea level is 160 mmHg. It changes if the altitude gets bigger.

"I saw this demonstration in a physics textbook."

Although physics textbooks often present historic experiments superficially, it is highly unlikely that a physics textbook, while describing the Torricelli's experiment, mentions a metal stick instead a glass tube and 160 mmHg instead of 760 mmHg.

Summing up, students' descriptions of the Torricelli's experiment, one of the most important in history of physics, missed essential details about how the experiment was actually carried out and how the mercury in the glass tube moved.

As today's students often search information on Internet, it is worth to mention that the presentation of Torricelli experiment in the lecture *"Pressure and the simple mercury barometer"* on the site of famous Khan Academy [26] is superficial and might mislead students. Namely, from the drawing that goes with narration one can conclude that (1) initially the tube was not fully filled with mercury and that (2) it was only turned upside down and immersed in the mercury in the container.

E. Other students' proposals

Many proposals, described by other students, aren't, in a strict sense, demonstrations showing convincingly the existence of atmospheric pressure but rather some physical facts or events related to changes of atmospheric pressure.

Two examples are:

Change of boiling point due to change of atmospheric pressure;

Behavior of some containers of cream and foods when transported from higher to lower places.

While in the first example students know that high pressure means higher boiling point (100 ^{0}C at the sea level and less at the bigger altitudes), in the second example description of containers' behavior and its relation with changes of atmospheric pressure is unclear.

Unclearness characterizes also a student's recollection of a talk with physics teacher about the role the atmospheric pressure plays in functioning of WC.

This student remembers better details of a video in which "a car was crushed by atmospheric pressure". A search on YouTube found out that the student might have likely seen a video shown on popular TV program *Mythbusters*. In that video, not a car but a wagon-cistern was spectacularly crushed after the air from cistern's interior was pumped out [27].

Some of students' proposals reveal presences of alternative conceptions. For example, one student cites the fact that a balloon filled with air goes down, but the one filled with helium goes up. Nevertheless, the student adds a revealing comment:

"Without atmospheric pressure the balloon with air (without helium in student's words) might be floating with no problem."

It sounds implicitly like a known alternative conception: gravity is caused (or assisted) by air pressure [28].

VII. CONCLUSIONS AND IMPLICATIONS FOR LEARNING AND TEACHING

The results of this qualitative, small-scale exploration study show convincingly that involved first-year physics students did not learn enough about simple and effective demonstrations that show that atmospheric pressure exists. It is surprising because the existence of atmospheric pressure makes possible working of many everyday artifacts, from drinking straws and vacuum cleaners to suction cups and atomizers. How to explain these disappointing results?

A popular explanation that students learn little or nothing in pre-university physics courses due to the lack of motivation and interest doesn't fit here well. As future physics students, they must have been interested in the science of their future professional life. So, possible explanations should be sought in other directions.

For almost half of the students, the explanation is obvious. According to their explicit declarations, they didn't see any classroom experiment or demonstration related to the atmospheric pressure. These declarations can be factual statements, meaning that they describe what really happened in their classrooms.

Nevertheless, it might be that their teachers did some demonstrations but they were forgotten later. It is likely to happen when students only passively observe what teachers do.

There are recently many research efforts to understand better what and how students learn from classroom science demonstrations. That learning process is rather complex and depends on many factors [29]. Nevertheless, some important experimental facts about students' observations of physics demonstrations are known [30, 31]:

(1) roughly one out of every five observations of a demonstration is inconsistent with the actual outcome; (2) students who understand the underlying concepts before observing the demonstration are more likely to observe it and remember it correctly; (3) students are more likely to observe a demonstration correctly if they predict the outcome first, regardless of whether the prediction is correct or not and (4) conceptual learning is contingent on the student making a correct observation.

There are also some useful practical suggestions for teachers on about how to use experiments [32] and demonstrations [33, 34, 35] to design and improve students' physics learning in classroom. A general agreement is that the quality of students' learning is directly related to their engagement and created emotional energy, especially if easy-to-find materials are employed [36]:

"Science demonstrations involving the use of familiar materials are resources offering opportunities for students and teachers to coexplore physical phenomena and interactions that can support the emergence of positive emotional energy. Instead of relying on students' prior experiences, demonstrations provide a shared resource for all participants. The conduct and results of the demonstration provide a frame of reference for successful interactions associated with discussions of observations and explanations".

Taking into account recent popularity of worldwide flipped-classroom movement in physics learning [37, 38, 39, 40, 41], in which home video-based learning takes an important part, a cautitory advice is necessary. If teachers don't produce themeslves video demonstrations related to effects of atmospheric pressures, they should carefully revise veracity of scientific content of suggested video for home watching and learning tasks.

Namely, some YouTube "educational videos" reveal problematic elements that might mislead students. Two examples suffice to provide evidence of that dangerous phenomenon. In the case of popular "egg in the bottle" demonstration, wrong idea is presented explicitly either in the title "Egg sucked into a jar" [42] or in the narrative "expanatory" text ("The vacuum is created and that vacuum is what sucks the egg in the bottle.") [43].

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