Pressure measurements by means of digital technology for educational purposes

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Abstract

Many scientific hot topics that are closely related can be taught by means of an interdisciplinary approach. An example of such a subject is pressure. Pressure measurements can be performed by classical instruments (manometers, barometers etc), but also by modern means, respectively by using digital technology. By employing during the physics hours of educational experiments based on data loggers (that have built-in sensors or attached external sensors), or scientific tablets (such as the Einstein Tablet), can definitely lead to a better understanding of the physical concept of pressure. These types of trials can determine as well whether the students are aware of the connections between physics and biology in this area and if this can effectively help them describe appropriate physical phenomena in the human body in connection for example with the blood pressure measurements. In this manuscript, we employed the Einstein Tablet, having attached the blood pressure, heart rate sensors and the LabMate data logger (that can also be connected to a computer) therefore transforming the entire system into a truly portable/wireless science lab. By also adding a pressure sensor to our system, one can perform experiments for highlighting how the external pressure variations can have an impact and change the total volume of certain bodies.

Keywords: sensor, blood pressure, interdisciplinarity

1. Introduction

Nowadays Physics and Chemistry are less affordable disciplines. There is a tendency to look for interesting topics that combine concepts and skills from different topics of natural sciences. It is extremely useful to associate the theory that should be assimilated in the context of everyday life so that physics is exemplified by processes encountered around us. Students are attracted to interdisciplinary connections, especially those related to medicine and the human body. Teachers should establish a direct connection between theory and practice, then their work will be easier and students could better understand the respective targeted subject (Volná and al, 2014). Students should be able to link information and knowledge from various disciplines in the field of science and create interdisciplinary relationships (Stal, 2011).

Lately, the experiment was not considered only as a supplement to the learning process. The experiment has even moved to the center of school learning in active learning strategies (Millenbah, 2003). By accomplishing this task, we managed to find an interesting subject in biology, but with a rich physical content, that could train more high school students which are not directly interested in physics. The laboratory in which computer information technology are implemented can clearly facilitate students’ motivation, can stimulate both their interest and increase the attraction to the discussed topic and boost the amount of knowledge acquired. Research shows that the use of technology contributes to and encourages the development of constructivist environments and supports the learning atmosphere in the classroom (Millar, 2005). Students explore new information about themselves and the processes that take place in the body, therefore making connections between physics and biology.

In the biophysics of complex systems we can observe physical aspects such as fluid dynamics in the circulatory system that can be compared to a tube system. The heart can be considered a pump and the center of the circulatory system. The heart uses pressure to push blood through our circulatory system of arteries, veins and capillaries, a system that makes up a coordinated functional unit and is perfectly adapted to the body's needs. The flow of blood through the arteries is normally laminar and sometimes turbulent. Blood circulation is subject to the continuity equation. In measuring blood pressure in the circulatory system we distinguish diastolic and systolic pressures, caused by mechanical contractions of the heart. These contractions occur as a result of electrical waves circulating along the heart muscle (Volná et al, 2014). For a doctor, the first indicator of a human body problem is the value of blood pressure. Peripheral pulse analysis to assess blood pressure was first described in the 19^{th} century (Sandrine et al, 2006). The pulse wave provides important information about the cardiovascular system. Noninvasive health check leads to the idea of real-time pulse wave monitoring, which has a crucial effect for early prevention of high blood pressure and improving treatment efficiency (Meng et al, 2019). Measuring blood pressure under different conditions is an example of applying fluid dynamics to our lives.

2. Materials and Method

The Einstein tablet operates on the Android system and, through the Google Play Store, includes access to thousands of different applications. Unlike a common tablet, apart from a microphone, headphone jack, USB port, an HDMI port, power outlet, SD card slot and reset button, the Einstein tablet has eight integrated sensors (from the factory) that can be used in the experimental study of scientific disciplines. The tablet already has Einstein World and MiLAB^{TM} installed. The tablet includes the humidity sensors, ultraviolet, light, the jack for the heart rate sensor and four ports for external sensors. Under the "Applications" icon on the screen one can access applications installed on the tablet, among which - MiLAB, the application employed in this paper. After launching the MiLAB application one can see the list of all available sensors. We can press the circle next to the sensor name (in our case ”Blood pressure”); via the sensor setting button we added additional properties to the measurement such as the time interval or the recording speed of the sensor. After clicking the ”playback” button, the MiLAB software began recording the active sensor data either for an already set time or the experiment could be interrupted at any time, by pressing the ”finish” button. At the end of the data collection process, the results are saved and later found in the ”archive” section. Data can be exported or shared with others via Google, email, Bluetooth, or a learning management system. The materials used in the experiment can be viewed separately in Figure 1 (a) and during the experiment in Figure 1 (b).

Figure 1 (a- left figure) Component parts of the experimental device: heart rate monitor (top left) heart rate sensor (top right) and sphygmomanometer (bottom)
(b-right figure) Experimental set-up for the determination of blood pressure

Accurate measurements can be made using the Einstein^{TM} heart rate sensor in Figures 1(a) and 1(b). This was connected simultaneously to the finger of the person whose pulse was also recorded on the Eistein Tablet, through the port of the heart rate sensor that the tablet possesses (through an external sensor). The heart rate sensor was selected and the blood pressure sensor measures the amount of pressure exerted by the blood on our arteries. Blood pressure reading involves two parts, namely: systolic reading which measures the pressure when the heart contracts and pushes blood through the circulatory system and diastolic reading, taken when the heart is at rest. Systolic pressure is always the higher of the two readings. Because people's bodies are different, blood pressure varies from person to person and can be affected by factors such as height, age, sex and is even influenced by diets. The blood pressure sensor (figure (1 a) below and figure 1(b)) contains several parts: an inflatable cuff, two hoses, an inflating pump, a pressure control button and the sensor itself (figure 5(a) top right). The sensor is compatible with MultiLAB for computers or MiLAB for tablets.

2.1 Blood pressure measurement

To start the experiment, we connected the two hoses to the sensor and the measurement interface, namely the Einstein tablet. We launched MiLAB and it automatically detected the sensor it displayed in the "View Launcher". We chose a three-minute data collection time and a sampling rate of 25 measurements per second. We wrapped the inflatable cuff around the arm of the test person. The winding should be located 2 cm above the bend of the elbow with the tubes along the elbow facing downwards, as shown in Figure 1 (b). We start the experiment by pressing the "Run" button. Using the inflation pump of the inflatable cuff, the latter was inflated slightly above the value of 180 mm col. Hg. We stopped pumping and made sure that the test person remained calm and did not move, in order to get accurate reading values. The measurement stops automatically after the set time expires and a result window appears on the tablet screen showing the systolic, diastolic pressure values and the pulse value, as observed in figure 3. With the above mentioned settings we obtained a total of 4500 values per measurement (the data was the stored in ".csv" format).

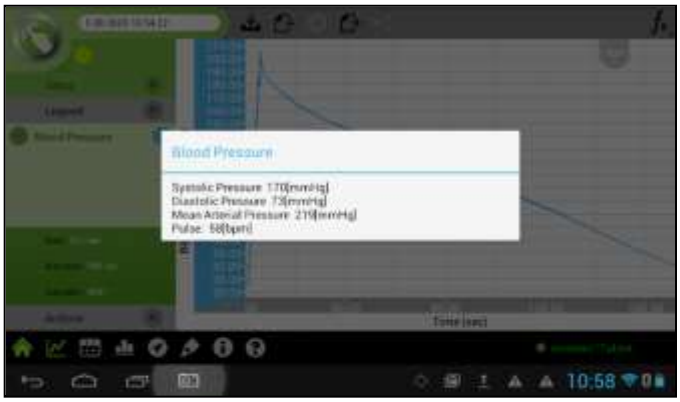


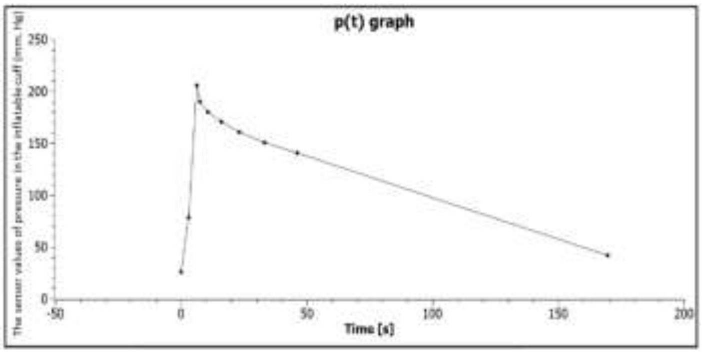
Figure 2 Graph of Presure in the cuff (mm. Hg) vs Time (s). One can also see the set measurement parameters on the left side

The pressure graph as a function of the time obtained is observed in figure 2; the pressure in the cuff being expressed in mm. col. Hg, and time in seconds. In our experiment, the obtained values were: 170 mm. col. Hg, 73 mm. col. Hg and 58 bpm, respectively.The values are shown in Figure 3 and can be written as 170/73 mm Hg.

Figure 3 The values obtained of Systolic Pressure, Diastolic Pressure and pulse at the end of the measurement

Time (s)	The sensor values of pressure in the cuff (mm. Hg)
0.04	25.883
3.04	78.329
6.32	205.699
7.64	190.16
10.76	180.262
16.08	170.735
23.32	160.74
33.24	150.848
46.28	140.303
169.6	41.608

Table 1



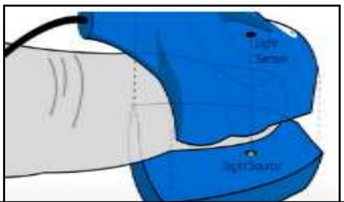
Experimental data from the pressure values sensor in the cuff
Figure 4 Time - Pressure in the cuff dependence via SciDAVis

In table 1 are presented some experimental data and in figure 8 the graph made by the students based on these data. The latter is very similar to the one on the tablet display.

2.2 Pulse measurement

In biophysics or medicine, the pulse means the effect of the heartbeat, manifested by the regular swelling or deflation of an artery, so it can be included in the category of periodic phenomena. This rhythmic beat is synchronous with the ventricular systole. It is obtained from the ”conflict” between the blood that already exists in the arterial system and the blood pushed during systole. There is a rhythmic relaxation of the artery that determines the ”pulse wave”. By accurately measuring the number of beats per minute by pulse wave we have a noninvasive diagnosis of a disease associated or not with high blood pressure. The pulse is correlated with various physiological diseases. We studied how the sensor works when the heart pumps blood into the capillaries in our fingers. Inside the clip there is a light source and a light sensor, as shown in Figure 5. The sensor was placed correctly on the finger, under the middle of the nail, so we made sure that nothing could block the light transmission from the light source to the sensor. The finger should be held still for five to ten seconds to read a correct first value. Any movement could interfere with the way light is transmitted. When the heart beats, the capillaries fill with blood. When the capillaries fill with blood, the light is blocked, the sensor capturing a heartbeat.

Figure 5 Location of the light source and the light sensor inside a finger heart rate monitor (adapted from https://www.youtube.com/watch?v=uOFbIHm3cCg*)*



Because the operation of the sensor is based on blocking a luminous flux, it is recommended that the experiment be performed away from a strong direct light source. The frequency/pulse obtained for our experiment was 58 bpm, as shown in Figure 6. The normal pulse rate is 60–80 beats per minute [book a)]. In the second measurement, in which we also used the heart rate monitor simultaneously, the red line in figure 6 indicates the pulse of the test person (a value of around 60 bmp, that is within normal limits).

Figure 6 Graph for the Heart Rate (bpm) and Pressure in the cuff versus Time

At the end of the experiment, press the sphygmomanometer control valve to release all the air from the inflatable cuff.

2.3 The influence of the external pressure on the shape of some balloons

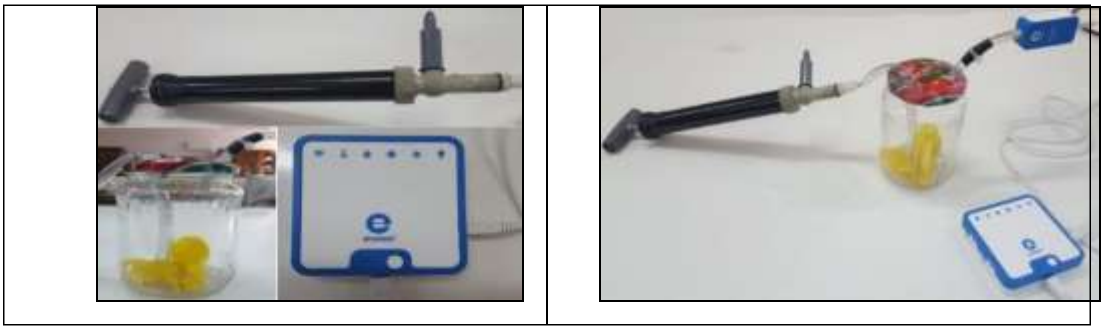


Figure 7 Experimental set up used for the pressure variation experiment

One slowly reduces the air pressure in the vacuum chamber by using the manual vacuum pump. As the air pressure in the jar decreases, the students noticed that the two balloons inflate, from which they concluded that the air pressure outside the balloons is lower than the air pressure inside the balloons p_0. The minimum pressure we can get in the vacuum chamber is 210^4Pa. Once the air valve is opened the balloons deflated again because the external pressure of the balloons returned to the initial value p_0 of 10^5Pa. The collected experimental data determined the shape of the graph in Figure 8, made with SciDAVis.

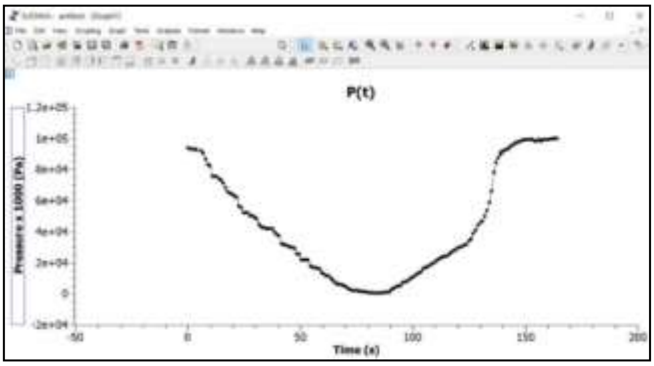


Figure 8 Time - Pressure dependence plot for the balloon experiment.

From the graph, the students noticed that the pressure did not decrease constantly as in the case of using an electric vacuum pump.

Conclusions:

Through the first experiment we were able to investigate how the concept of pressure in physics could be applied in biology, more specifically in human physiology. Specific sensors can be used both in physics experiments and in various biology experiments. We employed modern technology in education to obtain, process, store, convert and transmit data, namely the Einstein Tablet. We can study the variation of blood pressure during physical activities for example, by measuring blood pressure both before and after exercise. The accuracy of the heart rate sensor is ± 3 mm Hg, and of the heart rate monitor of one (one) bpm. It results that the method is ideal for school level, but also for coaches etc. The employed blood pressure sensor is designed for educational purposes only and should not be used for medical applications. The second experiment that we performed showed the inverse proportionality between pressure and volume when the laboratory air temperature remained constant.

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