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III. RESEARCH ON PRACTICAL CASES, DIDACTICS OF BIOLOGY AND SCIENCES

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Laboratory Works with Digital Resources – Motivative Means of Research for High Schools Pupils in Biology

Introduction

Modern Didactics proposes various methodological approaches to valorize the pupils' specific skills in Biology. The complexity of the instructional-educational process and the effectiveness of learning are based on active methods applied within the motivational activities of exploring the unknown with the help of information and communication technologies (ICT). The use of new technologies in the training process in the field of Nature Sciences allows the strengthening of interdisciplinary connections and the opening of new perspectives in personal and professional development [1].

The implementation of technological innovations and their adaptation to the specific of the study disciplines offers to the society multiple mechanisms of the development of the new ideas that underlie the socio-economic evolution, and to the pupils – possibilities to study some processes and laws based on technologies that allow to carry out investigations, formulate conclusions and crystallize own visions. People's interest towards this environment, in order to improve the learning process, has changed the approach of the educational process exceeding the limits of formal education. Learning becomes captivating when in classrooms, for example in Biology, there are opportunities to carry out the research in digital and virtual laboratories.

The digital laboratory is a means of investigation in the field of Nature Sciences in which devices, installations and instruments are used to obtain results represented by well-argued statistical data based on contemporary research methods [2–5].

The research, depending on the purpose, can generate qualities and behaviors by satisfying the needs of internal order, orienting the pupil to success by integrating several activities such as: solving problem situations, group and individual projects, communicating results, selecting the necessary information for formulating hypotheses, data processing and presentation of research results, etc. Thus, the research competence represents an integrated set of specific acquisitions practiced in different situations, by combining knowledge and experience, as well as the availability to mobilize, reorganize internal and external resources to achieve the purpose pursued [6].

The research at the high school level, as part of the training, designates the field in which the "scientific truth" is discovered through practical activities and through the methodological system proposed to the pupil in different learning contexts. The research activities in the school programs are based on the pupil's psychological nature. The products and results can be related to the type of extravert and intravert research pupil.

The extroverted pupil details and materializes the facts of the investigated object. He is dominated by curiosity; analytical spirit, cultivates the details, decomposing the whole into its component parts, interested in "forms", "images", "objects". This type of pupil is projective cultivating visible, spectacular aspects.

The introvert pupil is attracted by ideas, builds theoretical thinking systems, seeks to give explanations to those studied. He follows the clarity and ordering of the facts studied. This type of pupil is primarily interested in "ideas" and "qualities", being a theoretical type. He has the tendency to prove, to logically argue the asserted ones, being "critical" in discovering the truth.

The differentiation of the pupils according to the psychological nature, creates their own research attitude and style through: choosing the object of the research, the type of truth, the methodical attitude towards the research object, the motivation and the style of research, the choice of the research topic, the correspondence between the research and the pupil's personality [7]. The pupils' individuality according to the psychological nature mentioned above, must be adapted to the dynamic tendencies of the digital technologies era, which qualitatively enhance the thorough study of a topic or field.

The training process (Fig. 1) creatively enhances the pupils' cognitive abilities. The result of the process is appreciated according to the effort made by the teacher in planning the learning activities.

Based on the general structure of the training process, we identify that research is also found methodologically among the forms of organization of the didactic process.

During the Biology lessons, within the practical and laboratory work, there are planned actions in which pupils study certain processes and phenomena from nature.

Completing investigative activities with new applications for experimental work in the digital era helps to better understand the biological legitimacy specific to a living organism. For example, sensor sets of the digital laboratory can be applied as teaching tools for research. With their help, the competence of investigation and research in Biology is placed on a new stage of development, having a motivational character for all the actors of the educational system.

The sensors allow the development of a series of experimental activities, such as: cell diffusion; pulmonary respiration; thermoregulation and sweating; photosynthesis; germination of germinated seeds; soil humidity for plant growth; heart rate and cough; heart rate and physical activity; measuring the emotional stress values through the polygraph test; monitoring the yeast growth process; electrocardiogram; lung and spirometry parameters; temperature variations in the human body; breathing speed in humans; muscle strength, etc. [8].

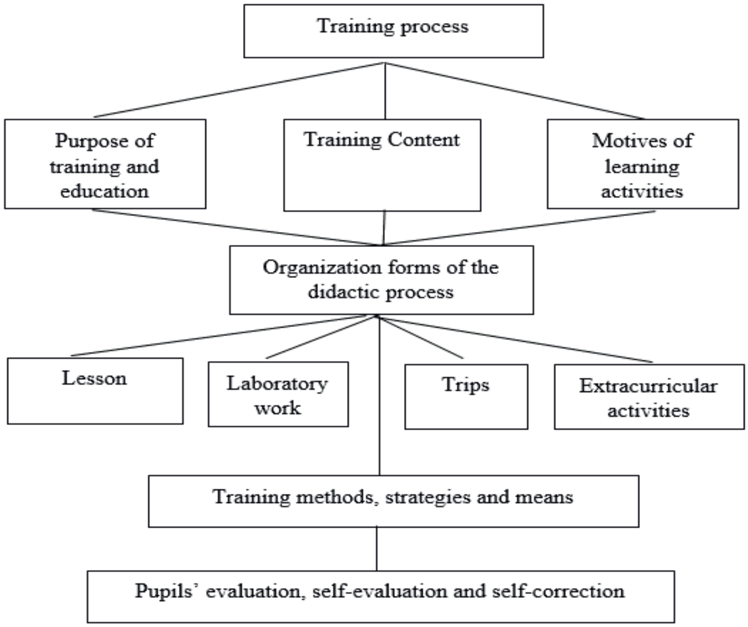


Fig. 1. Structure of the training process [7]

In the eleventh grade, the Anatomy and Physiology of the human body are studied according to the modular structure of the Biology discipline.

For example, in the Human Respiratory System module, by exploring respiratory devices, pupils can take research actions on the specificity of human breathing. The use of respiratory devices during laboratory work provides them with information about the physiology of this system in the form of pneumograms.

Materials and methods

In order to measure the respiratory rate and the comparison of the male and female respiratory rates, at rest and after physical exercise, the pupils researchers used the digital laboratory, which includes the sensor set and the specialized NeuLog software [9]. 28 students, aged 16–17 participated in the experiment.

Results and discussions

The laboratory work is carried out according to the stages established, for example, in the scientific work ***Respiration rate in humans***.

Objectives:

– to know the rate of lungs respiration;
– to measure the pupils' respiratory rates;
– to compare the rates of male and female breathing at rest and after exercise.

Required materials: PC application and NeuLog application, USB-200 module, NUL-236 recording sensor breathing belt, which is intended for educational purposes only.

Pulmonary ventilation

The human respiratory system is vitally important through the exchange of O_2 and CO_2 (respiratory gases), between the external (atmospheric) and the internal environment of the body.

Pulmonary ventilation includes processes that ensure air circulation from the external environment into pulmonary alveoli and from the alveoli into the external environment. Pulmonary ventilation occurs in a rhythmic sequence of inspiration and expiration.

Inspiration is an active process achieved by the contraction of the intercostal muscles and the diaphragm. In one minute, 1 in a state of rest, the human breathes about 6 liters of air, of which 1/3 remains in the upper airways and does not exchange O_2 and CO_2. The remaining 2/3 penetrate into the alveolar sacs, where they give off oxygen and receive carbon dioxide.

Expiration is a passive process conditioned by the relaxation of the intercostal muscles and the diaphragm. During the exhalation the lungs do not completely empty the air, because the lung volume is smaller than the chest one.

The two phases of lung breathing follow one another rhythmically, without pause, with a frequency of 14–16 per minute in men and 18 per minute in women. The frequency of respiration increases depending on O_2 consumption and CO_2 accumulation. Normal values for different age groups are: 18–30 breaths per minute in school children (6–12 years); 12–16 breaths per minute in adolescents (13–17); and 12–18 breaths per minute in adults.

The lung volume represents the total volume of air that the lung is able to retain after inspiration. It varies according to age, gender, race and physical development and it consists of four components:

The residual volume (VR = 1.8 l), which remains in the lungs after forced expiration;

The reserve expiratory volume (VER = 1.2 l), which can be eliminated from the lungs by forced expiration following an ordinary expiration;

The current volume (VC = 500 m l), which is the air introduced into the lungs following normal inhalation and which can be removed by exhalation;

The respiratory inspiratory volume (VIR = 3.6 l), which enters the lungs after normal inspiration through rapid inspiration.

Lung capacity is the volume of lung air at different stages of ventilation. All lung volumes and capacities are lower in women than in men (about 25%) and greater than 5800 l in athletes.

Calculation of lung capacity:

Inspirational capacity (CI) VC + VIR;

Functional residual capacity (CRF) CDF = VER + VR;

Vital capacity (CV) CV = VIR + VC + VER;

Total lung capacity (CPT) CPT = CV + VR.

Laboratory work progress:

For the work to be done, the digital sensor NeuLog Respiration Monitor Belt logger sensor NUL-236 (Fig. 2) should be connected to the recording belt of the measurement data of the respiratory rate, and the belt in turn should be fastened around the trunk of the human body (Fig. 3).

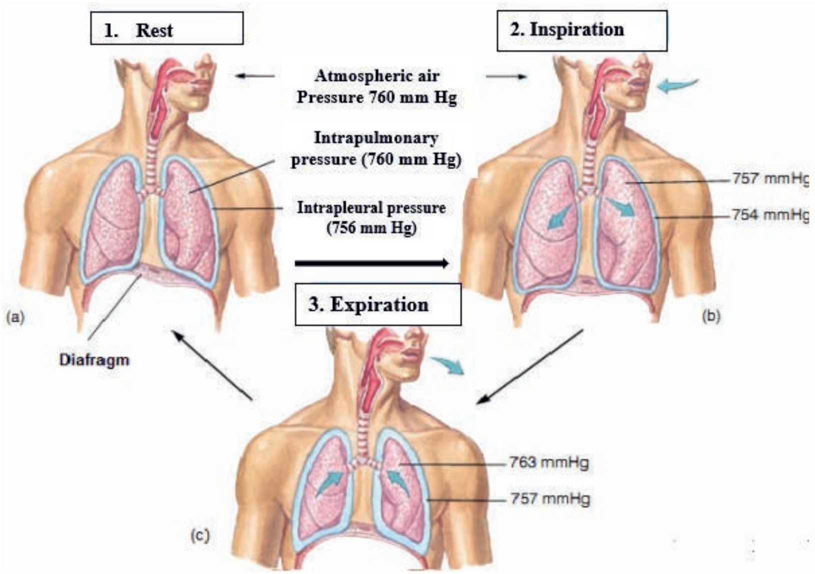


Fig. 2. Mechanics of pulmonary ventilation [8]

During the laboratory work, the belt connected to the sensor, will be applied according to the measurement of the pectoral and abdominal respiratory rate in resting state and after the physical exercise.

Fig. 3. Senzor digital NeuLog Respiration Monitor Belt logger sensor NUL-236

Fig. 4. Applying the belt for recording the measurement data of the respiratory rate

Sensor setting:

We connect the USB–200 module to the PC and check the connection of the NUL-236 sensor (Fig. 4).

Application of NeuLog software:

The NeuLog application needs to be checked if it has been identified by the sensor of the recording belt of the measurement data of the respiratory rate.

Fig. 5. Settings

Settings:

When the NeuLog application is opened, click the Settings button on the screen. The sensors connected for carrying out the laboratory work are automatically identified by the software; including disconnecting or connecting other sensors.

Fig. 6. The automatical identification by the NUL-236 sensor software connected to the computer for carrying out the work of measuring the respiratory rate in humans

When selecting a function button and the software key, you will be guided through the **Options** function:

a. "Run experiment" with the sensors connected to set the duration of the experiment and the sampling rate;
b. "One Step" Experiment;
c. "View" display with four options for one of the values of the connected sensors: Digital, Bar, Analog, gauge and Graphic accumulated;
d. "Experiment recorded" from the measurements data made and stored by the sensor;
e. "Open the experiment" from a saved file;
f. "Tools" for changing software settings or ID sensors.

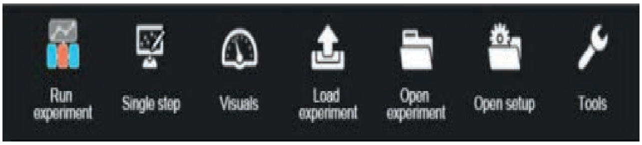


Fig. 7. The bar with the software setting options for the experiment

Testing and recording of data:

Two persons (male and female) participate in the research through laboratory work. Each person will be tested in several samples: at rest and after exercise (20 floats).

The first step of the laboratory work is to calculate and measure the respiratory rate in chest respiratory comfort.

In order not to cause discomfort, the breathing belt is well wrapped around the lower ribs and the diaphragm area. The rubber tube must be connected directly to the breathing belt. With the hand pump and the air release valve closure, the breathing belt is filled with air until it reaches the right shape. When you press the button with the Registration icon the necessary measurements will start.

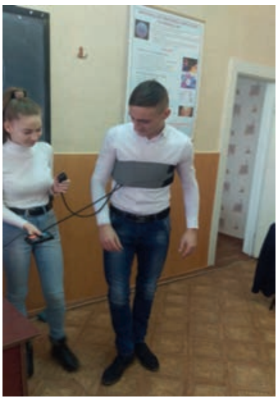


Fig. 8. Measurement of respiratory rate in chest respiratory comfort on a 17 year-old boy

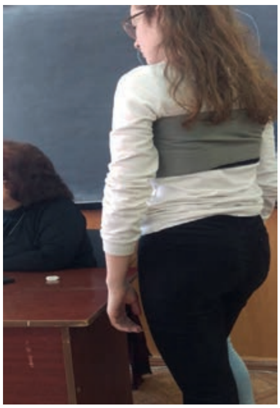


Fig. 9. Measurement of respiratory rate in the chest respiratory comfort on a 17 year-old girl

At the end of the measurement, click the Zoom icon to view the recorded graph.

The graphs obtained during the investigation and recorded using the NUL–236 sensor, represent a graph of the respiratory movements. They have ascending curves that indicate the inspirations of the respiratory act and descending curves, being specific to the expirations.

Through the Export and Save icons the measurement results recorded in the graph, depending on the purpose of the work, are analyzed and compared.

The results of the measurements from the first stage of the laboratory work are shown in the graphs below, corresponding to the male and female gender.

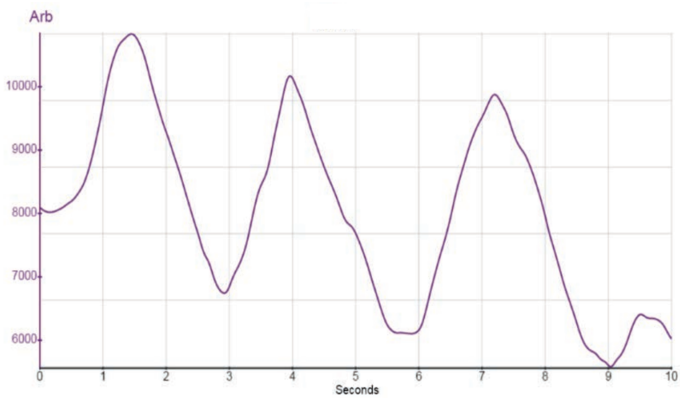


Fig. 10. The graph with the results of the respiratory rate measurement in chest respiratory comfort, on a 17 year-old boy

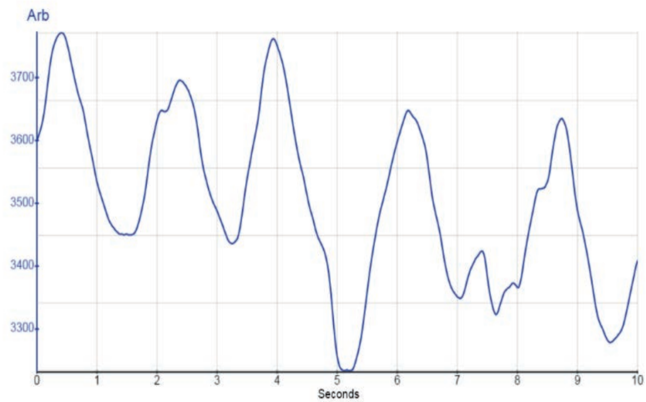


Fig. 11. The graph with the results of the respiratory rate measurement in chest respiratory comfort, on a 17 year-old girl

In the adolescent graph it is observed that in the chest respiratory comfort, the current volume (CV) constitutes 500 ml, and at the adolescent, it is approximately 400 ml. This difference is due to the boy's better physical training and greater lung capacity compared to the girl. At the same time, the differences are also caused by the physiological peculiarities between the greater lung capacity in the male versus the female. The frequency of respiration recorded in measurements in the female gender is higher than in the male gender, which corresponds to the values of adolescents aged 13–17 years who have from 12 to 16 breaths per minute.

Fig. 12. Measurement of respiratory rate in abdominal respiratory comfort on a 17 year-old boy

Fig. 13. Measurement of respiratory rate in abdominal respiratory comfort on a 17 year-old girl

The next stage of the laboratory work referred to the calculation and measurement of respiratory rate in abdominal respiratory comfort. Following the procedure from the previous stage of the laboratory work, actions are taken to record the respiratory rate.

Graphs from Fig. 14 and 15 show the results of the measurements of the abdominal respiratory rate in the resting state.

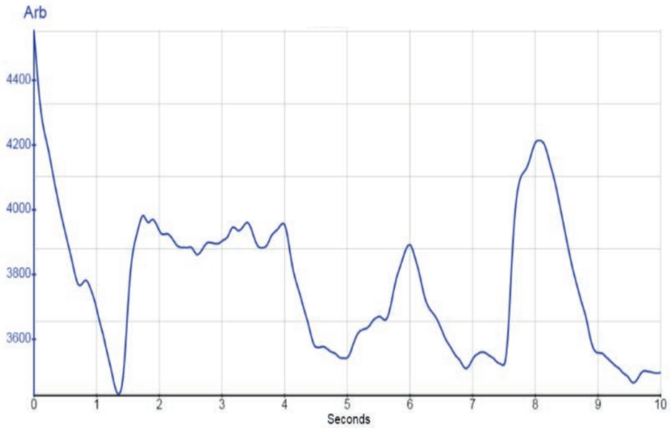


Fig. 14. The graph with the results of the measurement of the respiratory rate in abdominal respiratory comfort, on a 17 year-old boy

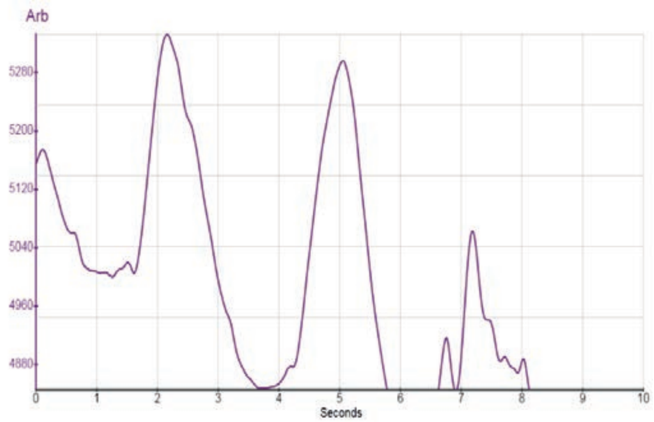


Fig. 15. The graph with the results of the measurement of the respiratory rate in abdominal respiratory comfort, on a 17 year-old girl

The values of these measurements differ from those of the pectoral breath (Figs. 10 and 11). Thus, at the boy there predominates the pectoral breathing, and at the girl there predominates the abdominal breathing.

Following these two measurements, the boy obtained values greater than 10,000 Arb as in the case of chest test, while the abdominal values are less than 5,000 Arb. In the student the values of the abdominal area are higher up to 5,300 Arb, compared to the values of the pectoral area up to 3,800 Arb. As a result, the female gender breathes predominantly through the abdominal area, rather than the chest area.

After a forced exercise (20 floats) and the measurement of the pectoral and abdominal respiratory rate, the following graphs were obtained.

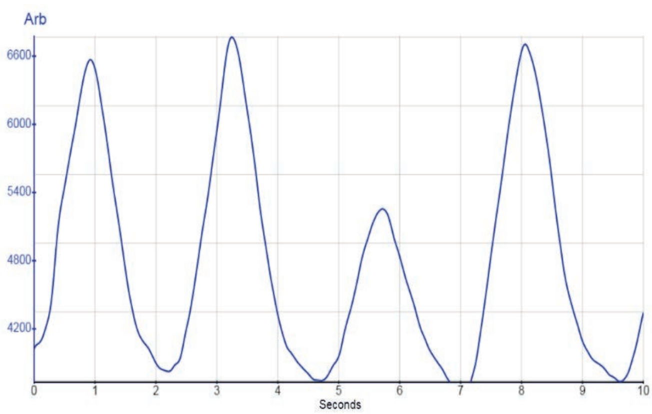


Fig. 16. The graph with the results of the measurement of the pectoral respiratory rate following physical effort, on a 17 year-old boy

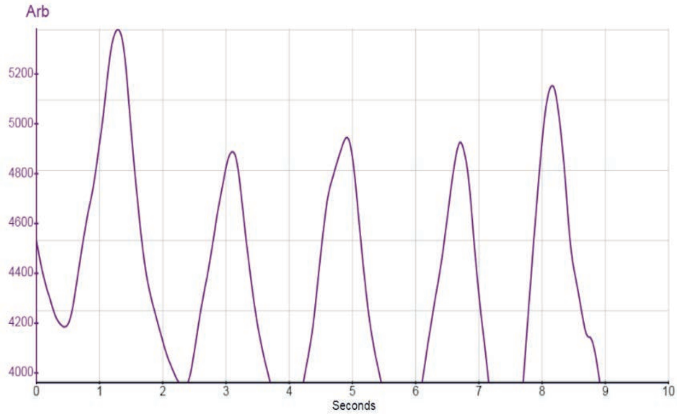


Fig. 17. The graph with the results of the measurement of the pectoral respiratory rate following physical effort, on a 17 year-old girl

The boy, after performing the physical exercises, obtained lower values in the pectoral area, and the girl, higher values as in the case of pectoral respiratory comfort. The measurement data are shown in Fig. 18 and 19.

At this stage, compared to the abdominal breathing stage at rest, the boy's respiration rates increased to 5,700 Arb, and at the girl decreased to 2,700 Arb.

We notice that after the physical exercise in the male, the breathing changes from the pectoral to the abdominal, obtaining abdominal values greater than the pectoral ones, whereas in the female, the abdominal breathing goes into the pectoral breathing.

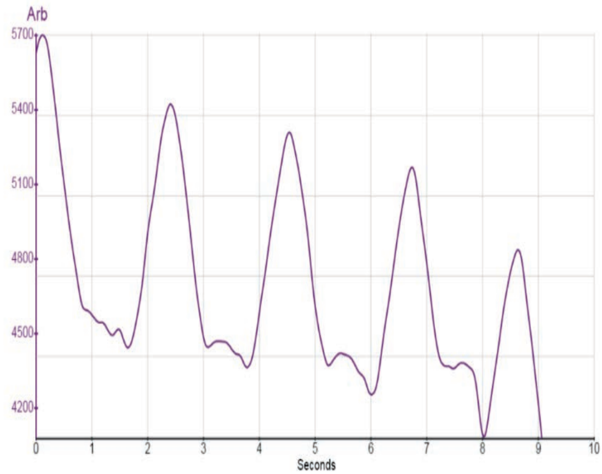


Fig. 18. The graph with the results of the measurement of the abdominal respiratory rate after the physical exercise, on a 17 year-old boy

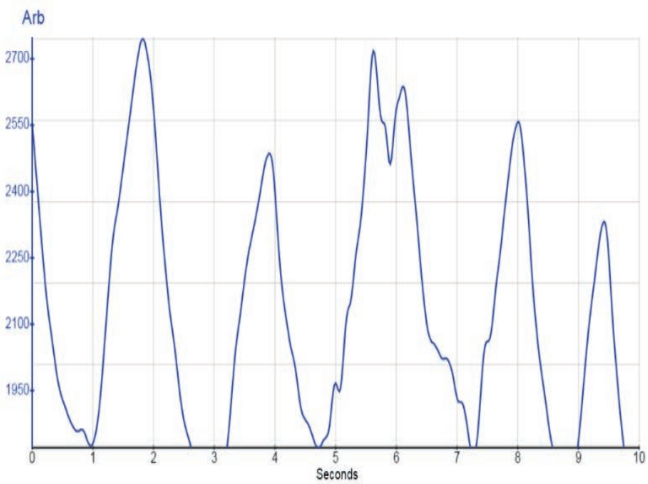
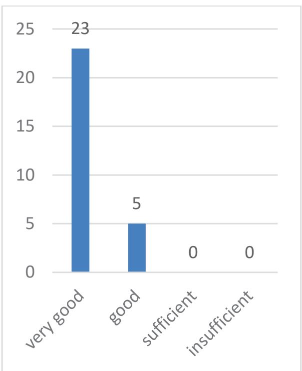
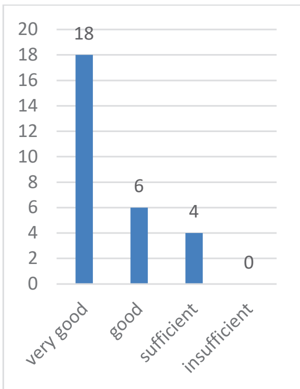
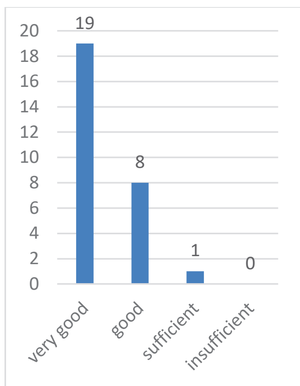


Fig. 19. The graph with the results of the measurement of the abdominal respiratory rate after the physical exercise, on a 17 year-old girl

For research purposes, a group of 28 pupils tested digital lab sensors. The obtained results were based on the integration and practice of the assembly necessary for the laboratory investigation. Their views on the work done with the help of digital sensors are presented in Table 1.

Table 1. The results of the student questioning regarding the usefulness of the sensors in the practical activity

Diagram 1 **The accessibility of the digital sensors in the accomplishment of the stages of the laboratory work**	**Diagram 2** **Accuracy of data recorded using digital sensors**	**Diagram 3** **The usefulness of digital sensors in drawing conclusions**
		

The results of the diagrams represent the very good motivational truth of the pupils regarding the activity undertaken. The combination of scientific investigation and laboratory work is a way of integrating the learning process with scientific research and arguing their importance in everyday life.

The use of the digital sensors in the investigation activities leads to the motivation of the pupils to explore ideas that personalize the instructional-educational process and make it efficient. The increase of the school performance is also due to the acquisition of certain skills, through the pedagogical methods suitable for learning.

The teacher's professional competences must be tangential with the competence of using the informational and communication technologies. The applicability of this knowledge helps to select the methods necessary for the research and investigation of the surrounding world through various forms of the didactic process organization.

Conclusions

Investigating the living world with the help of methods and means specific to improving the quality of life and environment, is one of the specific competences of biology. The laboratory work with the use of digital sensors, allowed the pupils to go through a creative, interdisciplinary teaching approach, also obtaining results of very good accuracy. The generalized conclusions in their own words, about the physiological peculiarities of the human body, will motivate them to promote a healthy lifestyle with a responsible attitude towards their own health and those around them.

The training through the implementation of new technologies in the didactic approach, motivates all educational actors to achieve the priority goals of education. The application of the competences specific to the school disciplines in different cases of learning, has a favorable impact on the development of the young generations' personality. This aspect will cause them to successfully integrate into the priority areas of human society based on attitudes and values.

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Laboratory Works with Digital Resources – Motivative Means of Research for High Schools Pupils in Biology

Abstract

The teacher's competence to select the most efficient methods, necessary for research using digital tools, is an imperative of modern didactics. The combination of digital skills and research methods helps pupils get involved in investigating the living world. Digital sensors enhance the applicative and interdisciplinary nature of laboratory work in Biology. The recorded results help young researchers discover scientific truths of processes and phenomena in nature. The conclusions formulated generate existing reflections on the processes and phenomena in the surrounding reality. Thus, we can mention that the digital Biology laboratory improves the quality of the instructive-educational process of the Biology discipline.

Keywords: biology, research, investigation, digital sensor, digital lab, breathing.

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