COMPLEX SMARTPHONE-BASED EXPERIMENT CARRIED OUT BY STUDENTS

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ABSTRACT

Experiments which are carried out by the students themselves play a crucial role in the process of teaching physics. Smartphone includes a number of sensors and the data received from the installed software can be used in the place of various physics laboratory instruments. The mobile phone was thus used to determine the acceleration of different types of movements (damped oscillation, pendulum, circular motion). All measurements were made by applying the "Accelerometer monitor", which can be downloaded free of charge from the internet onto a mobile phone. The project illustrates the most important features of project-based learning inasmuch as the students were expected to organize the process on their own, meanwhile the teacher acted as a "coach", merely supervising the students' work.

METHODS OF TRACING OF MOTION

In the process of teaching physics, kinematics is of utmost importance as it, actually, introduces the students into a quantitative approach to physics and makes them acquainted with the overlapping chain of thoughts related to observing, experimenting, measuring, building notions and elaborating theories. It is, therefore, necessary for this process to be grounded on convincing and easily repeatable measurements. By all means, it is not a simple task at all to define experimentally the position of an extended body in motion within a given system of coordinates even though the range of applicable procedures has ceaselessly evolved in the course of time. The rapid development of technology and the turn-out of computers have made fundamental changes in this area. Besides the classic methods – such as air cushion table (Fig.1.), electrostatic track recording, stroboscopy, photo gates with picket fences mounted to carts etc. – new modern techniques, such as laser and sonar based distance detection (e.g. V-Scope, Fig.2.), the GPS and procedures based on video technology (e.g. Videopoint, Webcam Laboratory, Fig.2.) and smartphones have also appeared.

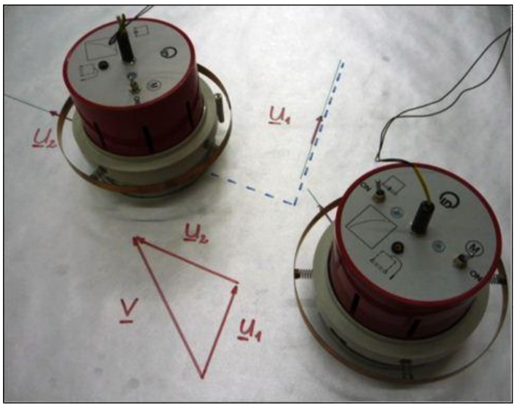

Fig.1. The air cushion table

Some of the aforementioned applications are perfectly suitable for being used by the students either individually or in pairs, maybe even in small group experimenting activities that involve measurements. Nevertheless, we have to highlight the fact that by skipping the principles outlined by the classical methodology of measurement and by switching over to the modern procedures directly, one would surely cause the loss of physical contents.

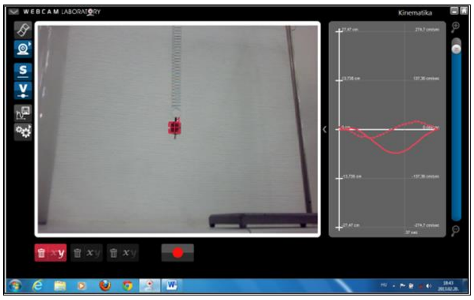

Fig.2. Investigation of circular motion using V-Scope and of an oscillating object with the Webcam Laboratory software

THE CRUCIAL ROLE OF PHYSICS EXPERIMENTS

It has already been acknowledged as a proven fact that the possibility of independently accomplished experimenting in the process of teaching physics is one of the best tools for raising the students' interest and awareness in natural phenomena, as well as the development of natural science-based thinking. Demonstration experiments which are presented by the teacher and experiments carried out by the students (Fig.3.) themselves or in small groups are equally important. What the students see with their own eyes is likely to be better retained in the mind, and thus it could be more easily recalled later and associated with other phenomena. It makes possible for the students to follow the path of researchers and thus grab hold of the basics of natural sciences and, furthermore, to consolidate their theoretical knowledge, to gain experience and to develop their practical skills. Experiments are known as being the "engines" of research - as they are also setting the grounds for the methodology of the teaching process in physics [1].

Fig.3. Student experimentation

Experiments may, of course, be grouped into different categories, and one sub-category that provides the students with the possibility to carry out experiments either individually or in small groups is called *student-centered experimenting*. Actually, this is the most beneficial option as it facilitates the students' activities meanwhile it also turns them from mere observers into active participants of the experimenting process.

THE PROJECT-BASED LEARNING (PBL)

In this paper a project work is presented which was shown at *the second Győr Science Festival* in the Mobilis Science Centre. During the measurement we want to put forward the most important characteristics of *project-based learning*. Project-based teaching, also known as the project-based teaching method is one of the newest and the most up-to-date methods, as the teaching process itself focuses on the students, aiming to develop their competencies necessary for the successful accomplishment of any practical task that they may have to cope with in their daily lives. The most important advantage of the method is that - should they be involved in either individual and/or group-work during the learning process - the students feel highly motivated, meanwhile the teacher becomes the co-ordinator – or, better to say, the moderator of the learning process instead of preserving his/her traditional role. The approach to the task is, therefore, characteristically interdisciplinary. Due to its pragmatism, as well as to the fact that both observation and laboratory experiments motivate its use in the process, project-based teaching is more than adequate for the teaching of natural sciences [2].

"Not a step without my mobile" These words are well-known to all of us. Smartphones and tablets have become organic parts of our lives and 85% of the children aged 12-13 have their own mobile phones. Getting used to them in their early childhood, the very young generation has become a full-time user of the available modern technical devices [3].

The use of digital technologies should receive a more important place in the curricula of various school subjects. Therefore, we have to teach our students that the aforementioned tools can be used for a lot more than just staying in touch with each other on social sites and/or via different chat programs. Quite unfortunately, some of the teachers are still reluctant to use any modern technologies because they either have difficulties in coping with them or they simply cannot find the time to get acquainted with the newly emerging means and methods. However, even these teachers must accept the fact that the new tools have given us exciting possibilities in our classroom activities [3].

The mentioned devices contain many sensors and data processing software that can be used genuinely while teaching physics. Besides the timer and calculator functions available on the older devices, various databases, e.g. the Pocket Physics application (Fig.4.), can be downloaded onto them. One of the most important sensors of any telephone is its microphone, which can be used very well to measure the intensity of the sound depending on distance or to perform the frequency analysis of different sources of sound during physics classes.

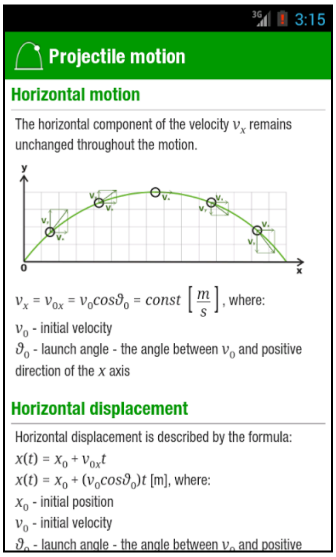

Fig.4. The Pocket Physics application

The already indispensable sensor of the smartphones is the tri-axial accelerometer which can be used to define the tilt of the phone as compared to the direction of gravitational acceleration. Of course, this sensor provides us with an almost infinite number of measurements as there are many applications meant to display graphs or to evaluate the measured data. Therefore, we can determine the measure of acceleration of various objects by attaching the telephone onto a moving body, a vibrating (e.g. a spring) system or a rotating one (e.g. a record player).

As it is rather difficult for the students to follow the measured data on the display of the telephone, it is worthwhile to transfer them, and perform the evaluation either on the monitor of the PC or on a digital board. During small group activities, it is enough to stand around the device or pass it around while analysing the results.

DETERMINING THE LOCATION OF THE ACCELERATION SENSOR OF THE TELEPHONE

The students can examine uniform circular motion in its real environment. A demo of a small-scale acceleration can be performed in the classroom by using a record player (30 cm in diameter). We can use the Accelerometer Monitor android apps, but quite a large number of other applications related to kinematic measurements can be downloaded from the internet free of charge. The sensor provides the values of acceleration along the three axes. Measuring the acceleration of the smartphone in different positions on the record player makes it possible to localise the position of the sensor within the smartphone.

By attaching the smartphone tightly to the record player with a piece of double-sided adhesive tape, we are able to determine the accurate location of the smartphone set in different positions and at various frequencies (Fig.5.).

Fig.5. The record player with the smartphone

We perform the measurement for a limited amount of time and then we stop it, thus having the possibility to read the measured data either on the display of the telephone or on the monitor of a PC - provided previous data transfer, of course. The three curves plotted in Fig.6. show the data related to the speed measured along the axes. The upper curve shows the data measured along the axis perpendicular to the figure (z), namely the value of gravitational acceleration, which we do not make use of presently. The middle curve shows the tangential component triggered during the rotational movement (x), which is now zero due to the steadiness of the rotational movement. The lowest range of data shows the radial component of the acceleration that we are to use subsequently in the course of our measurements (y).

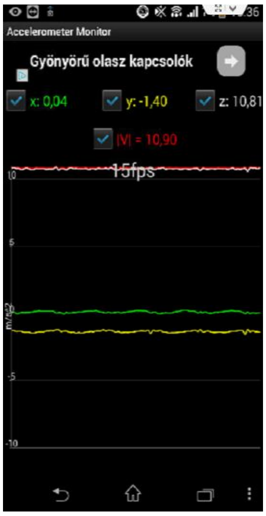

Fig.6. The values of the acceleration

If we know the number of rotations, we can specify the angular speed ω. The distance R of the revolving sensor from a central axis can be calculated:

$$n = 45\ \frac{1}{min} \qquad f = 0{,}75\ \frac{1}{s}$$

$$\omega = 2\pi f = 4{,}71\ \frac{1}{s}$$

$$R = \frac{a_{cp}}{\omega^2} = \frac{1{,}25\frac{m}{s^2}}{(4{,}71\frac{1}{s})^2} = 0{,}056\ \mathrm{m} = 5{,}6\ \mathrm{cm}$$

The measurement may be performed during extra-curricular programs, too, but by projecting the image of the monitor, we may also perform it during a classroom activity. However, if we make the exact parameters of the mobile phone available, the drawing of the figures may just as well form the matter of homework since the evaluation of the measured data may be done based on the images and by using a simple ruler.

In the course of the project, the children have also measured the acceleration in both the case of damped vibration and oscillation (see Fig.7.). Supported by the measured data, the students may solve several tasks such as finding the spring constant, defining the features of attenuation and calculating the moment of inertia and the resonance frequency. Furthermore, by investigating the “freefall” of the telephone, the students are also given the possibility to measure the local value of the force of gravity.

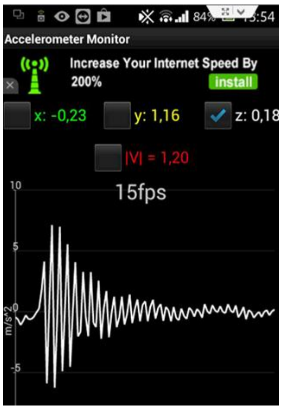

Fig.7. Acceleration-time graph of the damped oscillation

And, last but not least, we have to mention another great advantage of the smartphones: they are always at hand and their use does not require much previous preparation, just downloading the desired applications.

CONCLUSIONS

The modern technology has a right place in the physics classes of the high school, however, only when the students have mastered the classical procedures, analysed and plotted different graphs, and performed calculations. It would be a mistake to deprive our students of this experience and of its difficulties. If they can see that they draw a simple distance-time graph with their own hand which normally takes lots of minutes, they will appreciate that it's only a few seconds for a computer program. But the use of computer programs only makes sense if the students understand exactly how the program works and calculates. Therefore we should see that if we switch to the modern procedures without the knowledge of the measurement principle of the classic methods, the procedure loses its physical content. However, with no theoretical knowledge in the field, all of the above methods may be regarded only as simple PC- and/or telephone assisted games.

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