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Project-based ideas in optics for experimental activities using smartphones

Abstract: Experiments, which are carried out by the students themselves, play a crucial role in the process of teaching physics. It is an empirical fact, what the students see with their own eyes is likely to be better retained in mind and thus they could be more easily recalled later and associated with other phenomena. The independent student experimentation ensures that students are active, therefore they are not only observing the experimentation process but they are also participating in it making it possible for the students to follow the path of researchers. This 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.

Key words: smartphone, ICT, project-based learning, light, experimentation

Súhrn: Experimenty, ktoré sú vykonávané samotnými žiakmi predstavujú kľúčovú rolu vo vyučovaní fyziky. Je empirickou skúsenosťou, že čo žiak vidí na vlastné oči, je uchované väčšou pravdepodobnosťou a môže byť vyvolané ľahšie z jeho vedomia, a tiež ľahšie sa spája s inými javmi. Vlastné experimentovanie zabezpečuje aktivitu žiaka – nie je len pozorovateľom ale aj účastníkom, môže zažiť proces objavovania. Predkladaný článok ukazuje najpodstatnejšie rysy projektovo orientovaného vyučovania, nakoľko sa predpokladá, že žiak vykoná experiment podľa svojho, kým učiteľ pôsobí ako školiteľ, ktorý len dohliada na žiakovu prácu

Kĺúčové slová:

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The project-based learning (PBL)

Project-based learning, also known as the project-based teaching method is one of the up-to-date teaching techniques rooted in the constructivist pedagogy. This pedagogical trend appeared in the 18th century vocational schools for the first time, to be developed later on, in the 20th century, into one single methodology by William Heard Kilpatrick and John Dewey, [1] switching the focus of the educational process onto the student and successfully implementing the process in which students need to be trained in order to develop the competence for effective use. The main advantage of the method is that it motivates students to acquire knowledge, self-reliance and cooperative work skills together with their peers; meanwhile the teacher reverses the traditional 'teacher' role that focuses more on coordination and moderation. Traditionally, project-based teaching is a practice mainly used in the education of young children that also involves teaching science subjects as - due to observations - teaching science in school has a practical aspect. The prevalence and popularity of laboratory experiments are meant to show the use of the project method. [2]

For many young people and in many cases even for children, too, mobile devices such as smartphones and tablets are an integral part of their daily lives. Within the age group of 12 to 13-year-olds, 85 % of the student own smartphones, meaning that this age group is fully equipped with these devices. [3] It is very important, that we have to point out that their smartphones are more than the opportunity to be active in social networks. The use of digital technologies should receive a more important place in the curricula of various school subjects. Unfortunately, some of the teachers are afraid of this new challenge, because they often feel outdated. However, teachers must accept that the new digital technologies and devices can definitely be integrated into classroom activities in an exciting way.

During the project, the students have implemented the more and more popular Bring Your Own Device (BYOD) approach. [4] [5] According to the concept of the model, and also facilitated by his/her mobile device, every student sets up his/her own work environment, thus supporting a faster and a more efficient working process. The use of a privately owned device contributes largely to the motivation of the students, to a more colorful set-up of the classes, and also to the development of the students' digital competencies. However, it is worthwhile mentioning the possible disadvantages related to the use of mobile phones during classes as it may happen that some students do not own adequate instruments and, as such, their access to the experiment is almost automatically limited. A possible solution to the aforementioned situation would be collect any unused but still operating telephones (the presence of adequate sensors is a must), which we can lend to the students for targeted use.

Unfortunately, there is still the risk that the students who are less interested in Physics will not get engaged with the telephone application as required by the teacher but they will start browsing the internet (Facebook), download videos or just play. Any such activity is very difficult, if not impossible, to supervise - and it is even more so in a large classroom community. Another factor that may just increase the aforementioned risk is that the teacher is not really familiarized with the applications, thus the implementation process becomes slower, and then the student loses interest, gets bored and starts doing something else. Therefore, it is important that the measurements be done at the right pace.

As in most of the schools the use of mobile phones is being forbidden during classes - some schools even have the students hand in their phones on arrival; coordination is needed among the members of the teaching staff so that the students are permitted to use the devices. Moreover, it should also be mentioned that for such special classes Wi-Fi connection is also indispensable, this being another unsolved problem in many of our high schools.

During the measurement experiments, we have used Android phones but there are similar applications for Apple IPhones, as well as for newer generation Windows Phones, too.

Regarding the software requirements, a newer version of the Android 4 is needed; nevertheless, the shopping list does supply information on application compatibility.

Hardware requirements: any Android Smartphone. During our measurements, we have used a Samsung Galaxy S6 Edge.

Smartphone

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. [6] Previously, the mobile phone was thus used to determine the acceleration of different types of periodic movements (circular motion *(Fig.1.)*, damped oscillation *(Fig.2.)*, pendulum) in order to introduce the wave motion. Any measurements were executed by applying the "Accelerometer monitor", which can be downloaded free of charge from the internet onto the mobile phone. This application shows the measured acceleration along three axes. With the help of the measured data different calculations were made by the students, for example determination of the spring constant and the damping characteristic. [7]

Determining the location of the telephone acceleration sensor

The students can examine in the classroom the uniform circular motion within its real environment by using a record player. We can use the Accelerometer Monitor android applications but a number of other applications related to kinematics measurements can be downloaded from the internet free of charge. The sensor provides the values of acceleration along the three axes. The smartphone can be fixed to the record player with a piece of double-sided adhesive tape.

The three curves on the figure show the measured acceleration along each of the axis. The upper curve shows the measured data of the perpendicular axis of the figure. In the middle, the curve represents the tangential component of the acceleration of circular motion - showing quite naturally in this case, as the result of the uniform circular motion equals zero. The bottom sequence gives the radial component of the acceleration; this will be used in the later part for our measurement.

If we know the number of rotation (n), we can specify the frequency (f) and thereafter the angular speed (ω).

$$\omega = 2\pi f$$

$$R = \frac{a_{cp}}{\omega^2},$$

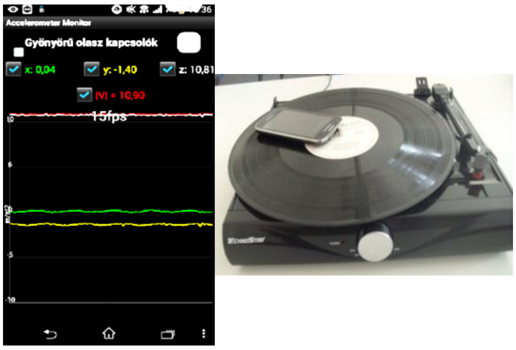

Fig.1: *Uniform circular motion*

Fig.2: *Damped oscillation*

Some of the measurements are perfectly suitable to be used by the students either individually or in pairs, maybe even in small group experimenting activities that involve measurements.

It was an interesting idea, the mobile phone was charged up during the measurement with the help of 4 simple dynamos mounted on a bicycle. The necessary direct voltage was powered by 4 Graetz bridge and the surplus current was used for operating a radio or a toy railway. [7]

Fig.3: *The charging of the smart phone*

Exploring light

During the studies of the different type of waves we were started dealing with the light. The experimental device was a homemade wooden box, which was made by one of the students *(Gergő Juhász)*. In the large size box four different light sources - such as traditional and halogen bulb, LED and CFL - were located with their own switch outside the box and the smartphone was placed and fixed in the box opposite the light source. When selecting the source of light, we have paid attention to the fairly equal diameters of the bulbs. While accomplishing our measurements we have used a halogen light bulb, a traditional 40 W one and a LED. For each light source and every light measurement experiment we have used the "Light sensor" to be found in the default men u of the telephone.

Fig.4: *The experimental device*

The first step we were watching the value of illumination in the case of these different light sources. These results were compared with the once that we got with a classic method, the Bunsen photometer, and we got nearly similar data. The measurement principle of the Bunsen photometer is: we light a greased-stained paper from two opposite sides with two different light sources, one of which is fixed and by moving the other light source we are looking for the distance where the stain is disappearing. At that point, the luminous flux of the two light sources is the same. As we know, the quotient of the illumination equals the quotient of the distances squared. Although during the measurement with Bunsen photometer we got the ratio of the luminous flux, and we measured with the phone the value of illumination, these two physical quantities are proportional, as the quotient of the luminous flux and the illuminating surface gives the illumination.

	Traditional	**LED**	**Halogen bulb**
Traditional	1	0,65	0,36
LED	1,55	1	0,56
Halogen bulb	2,74	1,79	1

Table 1: *The ratio of the luminous flux – Result with Bunsen photometer*

	Traditional	**LED**	**Halogen bulb**
Traditional	1	0,69	0,41
LED	1,45	1	0,61

Halogen bulb	2,41	1,66	1

Table 2: *The ratio of the illumination – Result with smartphone*

The light reflection is a well-known optic phenomenon for all students, because we can meet this in the course of countless ordinary situations. The following experiment is presents the phenomenon of the reflection of light in an indirect way. For that purpose each of the light sources were placed one after the other in each different position in the box. The students were individually measuring the values of illumination in the case of the different light sources and positions. They noticed that the values of illumination were changed. The reason is that the light reflects off the walls of the box differently. They had performed several measurements, and calculated the average of the measured data. As expected, we got almost similar data in case of the light sources in symmetrical positions, in 1-4 and 2-3 positions.

Posi-	LED	CFL	Halogen bulb	Traditional	AVERAGE
1.	51,460	74,038	89,993	66,086	70,394
2.	97,473	96,750	98,174	97,509	97,476
3.	100	100	100	100	100
4-	53,682	79,940	99,196	63,655	74,119

Table 3: *Result of the measurement - We had chosen the third position for the100 %.*

Besides, we wondered how the value of the illumination depended on the power of the light source. For this purpose, we had put together a simple circuit with a potentiometer, an analog voltmeter and ammeter, so the students could practice the reading of the data. The voltage and amperage were measured in the case of different conductivities and the students calculated the power in each case. The function was fitted to the data, and we received a nearly linear relationship between the power and the value of illumination.

Fig.5: *The circuit with a potentiometer, a voltmeter and an ammeter*

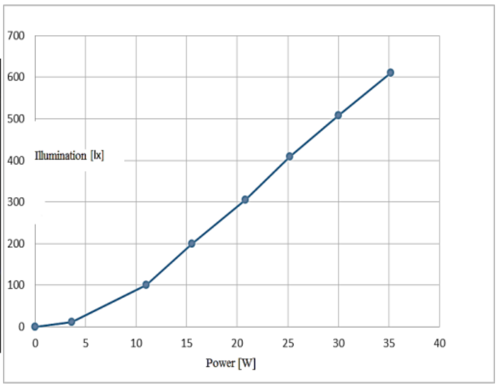

Fig.6: *The power-illumination function*

In addition, we were able to examine the light-transmission by the glass. For that purpose glass plates were placed into the box, increasing the number of the plates from 1 to 6. The students were measuring the changing of the value of the illumination in the case of the various number of glass plates. They noticed that the value of the illumination decreases exponentially depending on the number of the plates.

Fig.7: *Light transmission by glass*

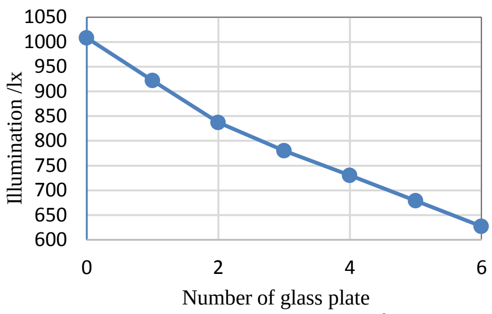

Fig.8: *The glass plate-illumination function*

After performing the measurements, we were able to determine the transmittance of the glass. We calculated with the formula of Fresnel reflection the reflectivity and the result was compared with our measured data. In this experiment, it was very important that the phone were placed directly in front of the light source because of the normal incidence.

The number of glass plate (n)	The Illumination (E_n/lx)	The transmittance (E_n/E_{n-1})
0	1008	-
1	922	0,915
2	837	0,908
3	780	0,932
4	730	0,935
5	679	0,930
6	627	0,923
average:		**0,924**
per one surface:		$\sqrt{\mathbf{0,924}} = \mathbf{0,961}$

Table 4: *The measured data*

The measured reflectivity (R):

$$R = 1 - 0{,}961 = 0{,}039\ (3{,}9\%)$$

The reflectivity is calculated with the formula of Fresnel reflection:

$$R = \left(\frac{n_0 - n_1}{n_0 + n_1} \right)^2$$

$n_0 = 1{,}517$ (glass), $n_1 = 1{,}0003$ (air) [8], $R = 0{,}042\ (4{,}2\%)$. We can say that we got nearly similar result with the two different methods.

Additional experiments from optic theme

Fig.9: *The law of reflection*

Finally, we had the opportunity to demonstrate the classical optic experiments in new form, with the help of laser beam and smart phone.

In addition, the law of refraction (for example in water) is proved by putting the phone under the thin-bottomed glass tank. The angle of incidence was measured via the geometric method with the help of trigonometric function.

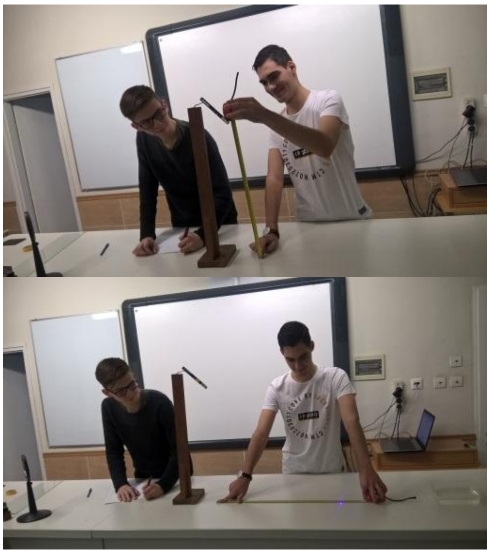

Fig.10: *Measuring of the angles*

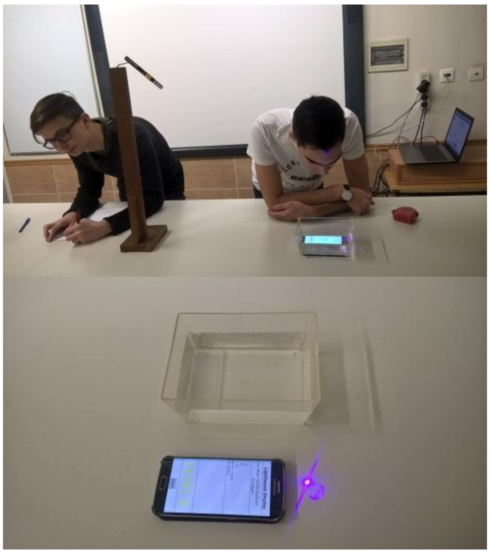

Fig.11: *Deflection of the laser beam*

Fig.12: *Determination of the focal point of the convex lens*

After that the angle of refraction was measured and having measured, we can see that the quotient of the sine of the angles is constant, and this give the index of refraction of the water for air. Besides, from the measured illumination values we can tell how much percent of the light reflects or absorbs. Moreover, we can determine the focal point of the spherical mirror or a convex lens. We need a reflector **-** it was a parabolic mirror – so that the light rays are parallel. We carry out the experiment in the traditional way, but instead of the screen we use the smart phone. We move the smart phone, and look for the distance, that the value of illumination is maximal.

Conclusions

The use of smartphones has several great advantages that we have to mention: they are always at hands and their use does not require previous preparation, just downloading the desired applications. Moreover, we cannot only demonstrate the laws, but the students can also solve exercises related to the experiments. Inasmuch as the students measure with their own devices, so they get different values. Therefore, they can practice the calculation of the average and the standard deviation during the evaluation.

One of the most defining purposes of our project has been for the qualitative analysis of the light-related phenomena to help subsequently our students understand and accept the wave-like features of light, as well as to urge them have a quantitative interpretation of any optical phenomena. The analysis of light phenomena via smartphones is rather new, the use of modern technical devices raising the children's interest for optics. The measurements have been executed by 9th and 10th grade students, while attending special competency-development classes. Neither the acquired knowledge in Physics, nor the instruments of Mathematics allow of a quantitative and accurate approach of optics at such an early stage of high school studies. Therefore, still unaware of the laws that describe light phenomena, the students yet manage to get some understanding of the nature and features of light via the aforementioned measurements. The notions of photometry - in other words the science of the measurement of light – are rather ignored during Physics classes although they are very much interconnected with our daily lives. As such, I do feel it necessary to give this matter some thought - if not during classes then at least as extra-curricular activity - in order to clear up some basic notions and laws concerning photometry.

Besides class activity, the students will thus have the opportunity to measure and analyze, as well as to perform any resulting calculations.

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R e f e r e n c e s

[1] Fűzné, Dr. Kószó, Mária, Projects on Environmental Education as Means and Methods to Develop Abilities Used in the Training of Lower Primary Teachers. Manuscript: Szeged, 2013.

[2] Thomas, John, W, PhD, A review of research on project-based learning, 2000

[3] Oprea, M., Miron, C. *Mobile phones in the modern teaching of physics,* Romanian Reports in Physics, Volume 66, Number 4, 2014; 2013

[4] Devaney, Laura (2012):'Bring your own device' catching on in schools E-School News. Technology News for Today´s K-20 Educator

[5] Jarosievitz Dr, Beáta: BYOD and Turn to your Neighbours, In: Studies from Eduacation and Society Edited by Tibor János Karlovitz; International Research Institute, pp. 67-72. ISBN: 978-80-89691-38-8

[6] Jarosievitz Dr, Beáta: The impact of ICT and multimedia used to flip the classroom (Physics lectures) via Smart phones and tablets In: Proceedings of the 20th International Conference on Multimedia in Physics Teaching and Learning, Edited by Lars-Jochen Thoms and Raimund Girwidz, Published by the European Physical Society; September 9–11, 2015; at LMU Munich, Germany; Volume number: 39 B.; pp. 357-363, ISBN: 978-2-914771-94-8

[7] Finta, Zsanett, Complex smartphone-based experiment carried out by students, Teaching Physics Innovatively (TPI-2015)

[8] http://emtoolbox.nist.gov/Wavelength/Ciddor.asp

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