Applying digital media in elementary and high school education for improving students' creativity, problem solving and individual experiments

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Introduction

Starting from the interest into technology of my students I have reached the conclusion that experiments and digital technology conveying them to students can play an important role in reforming the teaching of Physics. Besides teaching I have held experimental presentations nationwide both for teachers and students of Physics. The feedback received on site and after the presentations has been important and useful, and has showed me new directions in my further work.

Based on the projects carried out and experiments recorded together with my students we have managed to proceed with making our film in the studio of MOZAIK publishing company, so I could present my work aiding the teaching/learning of Physics to a much wider audience.

Computers, smart phones and the Internet are indispensable accessories of students' everyday life. They exchange letters, find entertainment, make new friends, and extend and deepen their knowledge in the virtual space accessible with these appliances. In this digital world visuality plays a more determining part than lengthy reading. A very strong motivation is needed to induce students to read several pages of informative texts. In this regard our education is one step behind. The above listed technological achievements were all created by natural sciences, but in our teaching process we do not really exploit the possibilities offered by digital technology. We must be wary, but we need to make a step forward. Caution is primarily justified by the fact that many times the digital world moves away from actual everyday life; however, natural sciences examine strictly the laws of our real environment. A good solution might be to exploit our students' interest and deliberately use digital technology to draw their attention to real life phenomena and their direct experimental recognition. Photos and video films, as certain forms of experimental documentation of reality, might be used to compose creative Physics assignments. Video films with a supplementary computer motion analyzing program might replace a measurement.

Students generally like to experiment, but besides setting them the exercises, they need control and guidance. Digital teaching aids and software illustrated with videos provide excellent possibilities to assist in student experiments at home and at school. Developing teaching aids which present real phenomena and assist in related creative problem solving and individual student experiments, elaborating the methodology of their use, and the testing of them at school sessions might efficiently contribute to raising the interest of students into natural sciences.

While I was a PhD student I worked as a teacher of Mathematics, Physics and Arts in an average high school with students small in numbers (altogether 50-60 students in the four grades). During this period I managed to raise the interest into Physics not only of students with orientation towards technical careers but also of students with average or weaker skills. In many cases I have managed to define certain parts of the curriculum only qualitatively and sometimes I had to search for new ways to get my students to understand certain laws of physics. Only rarely did we manage to enter Physics competitions at the county level, but the feedback I received from formerly graduated students reassured me that they retain their positive attitude to physics even after high school graduation.

Project-work to refute pseudo-science statements

According to the National Curriculum enlightening activities against pseudo-science theories represent an important task for physics teaching. Teachers should conduct permanent informational activity but that, on its own, according to my previous experience, is not enough. A really efficient informational activity means active participation of students at proving or refuting assertions which might even seem to be scientific ones.

Argument 1. :

I have shown that our students can be protected against pseudo-scientific views if they are convinced, that they should not believe automatically in any, seemingly scientific information, or argument, even if appeared in the written or spoken media, in books or on the internet.

High school students are motivated by the search for the scientific truth. Making their own experiments, measurements, through internal conflicts, students will understand that not every proposition published in the written or spoken media is necessarily true. So it is recommended to treat them critically and, if possible, check them experimentally. Based on those above I conducted two project-work activities at which students took part voluntarily in their spare time.

One of the projects is based on a contradiction between Gábor Horváth et al's article, published in the 'Fizikai Szemle' (Physics Review) (1), and assertions of a secondary school exercise book.

The idea for another project has also been given by students and it refers to a piece of ''news'' heard on the media, namely:

'Can waterdrops focus sunshine and induce burns on plant leaves?'

During project-work students not only repeated experience of the authors of the article but also confirmed with further results their claim that focusing effect of waterdrops cannot burn out leaves.

In an own experiment, with the help of the Webcam Laboratory measuring computer system, we examined shape transformation of waterdrops during evaporation of drops.

We found that during evaporation waterdrops had got flattened, their focus-distance had increased quickly and so - energy concentration below under-drop area of the leaves had decreased. The results show that – also due to the fast evaporation of the waterdrops - leaves would not get burnt.

''Is microwave-boiled water harmful to plants?''

A worrying piece of news appeared in the media says that water warmed up in microwave ovens would be harmful to living organisms. It says plant seeds watered with such water will not spring or will grow slowly. In order to prove the assertion would be true, students set up control-experiments which were accomplished through several weeks of work. Using web-cameras and a computer, they measured the growth speed of experimental plants watered with various kinds of water. The result of the experiment has undoubtedly confirmed that the assertion appeared in the media was not right.

During talks that followed the projects, we discussed how such false claims could have been published in the media. Possible causes could have ranged from superficial credulity to personal interest-based conscious falsification. Students working on the projects must have understood the R. Feynman Nobel-prize winning physicist's assertion I often used to quote:

'the only criteria of the scientific truth is the experiment'

(*R. P. Feyman, R. B. Leighton, M. Sands: Mai Fizika 1, Műszaki Könyvkiadó, Budapest. 1970 (angol nyelvű kiadás –English version, 1963)*).

*[1] Egri Ádám, Horváth Gábor, Horváth Ákos, Kriska György (2010) Beégethetik-e napsütésben a leveleket a rájuk tapadt vízcseppek?(*Can Sunlit Leaves With Liquid Drops On Their Surface Be Burnt?) *(Clearing a bio-optical problem full of false beliefs) Egy tévhitekkel terhes biooptikai probléma tisztázása. I. rész (Part I.): Napfény forgásszimmetrikus vízcseppek általi fókuszálásának számítógépes vizsgálata (Computer Control of the Sunshine Focused by Rotation-Symetrical Waterdrops). Fizikai Szemle 60: 1-10 + címlap*

Argument 1. Bibliography:

- Stonawski T.: Can Sunlit Leaves With Liquid Drops On Their Surface Be Burnt? Physics Competitions, ISSN 1389-6458, Vol. 15 No. 1 & 2 2013 pp. 41.-51.
- Stonawski T. : Folyadékcseppes levelek napégése – egy biooptikai diákkísérlet, Fizikai szemle 2011/7-8, pp. 259.-, Budapest, 2011. (HU ISSN 0015-3257). (Sunburning Of Leaves With Waterdrops On Them – a bio-optical student experiment)

Aspects of car driving and of the Highway Code examined in a school study-circle special program

An important task of physics teaching is to show how physics has multiple connections to our everyday life. School class presentations of practical applications are hindered first of all by the limits of educational curriculum. One possible solution is to mention some interesting applications during school classes and then give them a more detailed discussion at the school study-circles. An interesting topic can be, for example, car driving, a good issue in teaching mechanics. Most students are willing to get their driving licences at this age so physics of car driving is a topic they should be interested in.

Argument 2.

I set up a school study-circle program focused on how to apply laws of physics just studied on problems of car driving. The aim is to extend physics knowledge beyond its school class limits and practice physics laws acquired at the school classes; also to complete those with imformation that have not been included into the curriculum but have practical importance for everyday life. Beside school class knowledge we make students realize that Highway Code rules are - in many cases - based on the laws of physics.

Theoretical analysis of real traffic situations has become more interesting due to simple calculations, students' own measurements, PC-evaluations of mobile phone videos and model-experiments.

In the recent years the topic of rotation has not been included into the secondary education curriculum. Applying problems of car driving in the school study-circles I extended the basic study material with the kinematics and dynamics of rotation and rolling.

I introduced the school study-circle program during the 2012/2013 schoolyear with high-school students from forms 9-10-11.
Most students of mine do not learn physics with the intention of using it in their further studies. In spite of that they took active part in the school study-circle activities and they were very interested in those. That proves that experimental approach of practical problems that interests students, motivates even the ones who are not really keen on discovering the mysteries of theoretical physics.

Argument 2 Bibliography:

[P1] Stonawski T. : Gulliver matchboxai– töréstesztek valóságos és játékautókon, Fizikai szemle 2012/1, pp. 28.-32. Budapest, 2012. (HU ISSN 0015-3257). (Gulliver's "matchboxes" – Crash Tests On Real- And Toy Cars)

[P2] Stonawski T. : » BIZTONSÁGOS «ÜTKÖZÉSEK, Fizikai szemle 2013/3, pp. 87.-89. Budapest,2013. (HU ISSN 0015-3257).(Safe Crashes)

[P3] Stonawski T. : A követési távolság fizikája, Fizikai szemle 2013/7-8, pp. 248.-251. Budapest, 2013. (HU ISSN 0015-3257).(Physics of Distance of Following in Traffic)

Extending physics knowledge through slow motion video analysis projects

Measurements of very slow or even too fast motions, difficult to see with the naked eye, represent an exciting challenge to secondary school students. Experiments become more interesting when students can register motions using special videotechnics methods (slowing down and speeding up). Then, speeding up the motion, evaluation can be done with the help of a computer motion-analysing software.
As my students have been interested in those above, I organized facultative project-work for them, on several topics. Beside computer videotechnics, students were also attracted by the fact that the topics examined were rather connected to everyday phenomena than to the compulsory school curriculum.

Argument 3.
As shown above, students are interested in modern, computer-based measuring technics. AWebcam Laboratory computer-based measuring system, with webcam, developed for school purposes, makes students able to examine quantitative aspects of everyday slow motions. While using the measuring system, they acquire a lot of theoretical and practical knowledge, first of all regarding the examined phenomena (in our case about the moon and the clouds), all that a lot beyond secondary school curriculum. Working together with their teacher means motivation to students. It means something different from school classes. It is a 'workmate' relationship which allows the teacher to transmit information about work methods and informal talks let them share a lot of theoretical knowledge as well.

I proved those above through two projects, on the following topics:

a.) What speed do clouds move at in the sky?

We started the topic of cloud motion, experimentally defining the view angle that corresponds to the full camera photo width. Then, using the changing of the view angle in a given period of time, we measured how a chosen specific point of the moving cloud moved away.

In order to measure the height of the clouds we applied a method to measure the height of the objects in the area. The idea of the method is: Even after the sun diasppears beyond horizon, high objects in the area are touched by the sun for given different times, depending on their height. Results of the measurements obtained by our team agree with those given by the meteorology's special literature. The job done together, beside developing experimental skills, has given good opportunity to know the special meteorology, the atmosphere-physics phenomena and has given an insight into the background of the specific internet data communication system as well.

b) Experimental examination of how the moon moves in the sky and defining of its rotation time

While analysing webcam photos of the moon, students had to consider the apparent motion of the moon in order to take conclusions on its rotation speed – with the help of the measurement data. Based on the measurement data, they defined the direction of the moon rotation and got an approximate value of the rotation speed too. Beside extending and deepening their basic knowledge of astronomy, students managed to get practical information on how to shoot videos and take photos of the moon as well.

Argument 3. Bibliography:

[P1] Stonawski T.: Felhők magasságának mérése (Measurement Of Cloud Height), Fizikai szemle 2014/9, pp. 320.-324. Budapest, 2014. (HU ISSN 0015-3257).

[P2] Stonawski T. : A Hold keringési sebességének a mérése (Measurement Of Moon Rotation Speed), Fizikai szemle 2015/2, pp. 61.-64. Budapest, 2015. (HU ISSN 0015-3257).

Video analysis of fast motions – knowing chaotic motions

Examination of details of fast processes requires high frequency videos. Several students of mine have smart phones which are able to shoot 120/pictures/sec videos.

4-time slowed down video shootings can be well evaluated with the help of motion analysis computer programmes. Applying such a method and using own made videos we examined free falls, collisions and wet rocket launchings. During our school study-circle project, based on one of the examples given in a Márton Gruiz and Tamás Tél's book, the 'Chaotic dynamics', and with the help of high frequency videos, we managed to examine chaotic behaviour of balls moving in differently shaped bowls.

Argument 4.

I showed that using technics close to students is a motivating factor that helps giving them knowledge, that hardly could have been acquired without the necessary technical background and the students' personal involvement.

The initial motivation that has convinced students to accept the project was the use of special videotechnics from their mobile phones, plus the promised opportunity to get an insight into an often mentioned chapter of modern physics, that of the 'theory of chaos'.

By doing the job their attention focused more and more on the specific topic.

Students became interested in what they could find out during examination of motion of a ball rolling in an assymmetric glass bowl along of an imprevisibly complicated trajectory.

Both the experiment and the video shooting needed theoretical background. So we agreed that, from theoretical point of view, through a good approach, the shape of the flat bowl could be considered as a two-changeable potential factor. The theory did not prove to be easy to understand but it has been validated through computer-modelling of the motion.

We did a computer simulation of the ball movements considering (linear) friction according to the real arrangement. From that moment on, experiment and simulation went on simultaneously (my students did not take part at the make up of the simulation programme). The ball was launched, both in the experiment and the simulation, from the edge of the bowl, with various starting parametres (speed, direction). Based on the computer analysis of the filmed experiments, students defined the initial conditions of the motions and had trajectories of the balls drawn. The computer simulation of the motion has been done by fixing the initial conditions obtained from the video analysis.
Then, my students and I compared the ball movement video and the trajectory curves given by the simulated motion that was based on a proper initial condition. For a long time, however, balls which were launched close to one another did not remain close for long, neither in the experiment nor in the simulation. This way we managed to prove the basic feature of chaos, namely sensitivity to the initial condition in both approaches. Using different shape bowls, we also realized that chaotic specificity of motions disappears in rotation symmetrical bowls.
The experiment and the simulations made students understand the essence of the computer-based simulation and also, at a basic level, got to know the basic features of chaotic motions and the essential differences of those versus simple motions studied at school.
(2) T.Tél, M.Gruiz, Chaotic dynamics, An Introduction Based On Classical Mechanics, Cambridge University Press, Cambridge, 2006

Argument 4 Bibliography. :

[P1] Stonawski T. : A digitális technika sodrában: Káosz a tálban (In the whirl of digital technics: Chaos in the bowl) Természettudomány tanítása korszerűen és vonzóan (Modern Manner And Attractive Teaching Of Natural Sciences), szerk: Tasnádi P., ELTE, TTK, pp. 311.-314. Budapest, 2011. (ISBN 978-963-284-224-0)

Scientific thinking and artistic representation mutual support

Being a teacher of Mathematics, Physics and Arts, I thought it was my task to show my students that, despite public belief, science and arts are not so far from one another.
The basic problem of modern physics teaching in secondary education is that its most important terms and notions are difficult to understand for a layman. True, they can be understood with the help of high mathematics, but the basics of the latter are missing from secondary schools. Real art also faces similar problems because it reflects life's beauties and problems coded in colours and in bidimensional shapes and represents a challenge to our soul's world. I believe, making physics and art getting closer to one another, can be useful to both of them. Getting to know artistic creations, even if not quite at an exact level, but on that of a certain feeling, could help making students accept even difficult-to-understand modern physics' terms and notions.

Argument 5

I elaborated a method to make physics and painting get closer to one another. Paintings give their eras pretty good science-images. Taking advantage of that fact and making use of artistic representations I have been doing my best to make physics lessons more colourful and interesting. Being surprised at the beginning, students eventually accept that science and art are

parts of the same universal culture. Art and science being connected this way, students would be surprised that their natural sense of beauty, instinctive sense of proportions can be expressed mathematically. Through photos and pictures we demonstrate that we can see something proportionally nice that corresponds to the so called 'golden section' rules.
In teaching physics, difficult terms and notions of modern microphysics, can be efficiently backed with painting analogies. The discussion of Heisenberg-type uncertainty relation principle and that of the electron wave function are introduced through a shared analysis of paintings which represent motion. Artists make motions be felt according to the uncertainty relation, distorsioning proportions and making contours fade away, namely, suggesting uncertainty of the place.
Learning (electron) wave function we turn back to pictures and, in order to strengthen analogy, to ''describe'' the jumping horse of Gericault's we introduce the ''horse function''. Also, connected to ''Dynamics of the lead-driven dog''picture of Giacomo Balla's we introduce the ''dog function''.
Similarly to the wave function of the electron, the shapes of continuative functions we have defined, are specific to the moving animals' probable location and speed.
In my view, description of the electron function and, parallely presented, artistic motion representations, both helped students accept the difficult-to-understand theory of quantum mechanics.

Argument 5. Bibliography. :

[P8] Stonawski T.: Gericault és az elektron, A FIZIKA, MATEMATIKA ÉS MŰVÉSZET TALÁLKOZÁSA AZ OKTATÁSBAN, KUTATÁSBAN (Meeting Of Physics, Mathematics And Arts In Education And Research), Nemzetközi konferencia magyarul tanító művésztanárok és szaktanárok számára (International Conference for Gungarian Spoken Teachers of Artist-Teachers and Teachers Of Science Subjects, szerk.: Juhász A., Tél T., ELTE, TTK, Marosvásárhely, 2012. augusztus 15-18., pp. 135.-140., Budapest, 2013. (ISBN 978-963-284-346-9)

[P9] Stonawski T.: Az aranymetszés az európai festészetben (Golden section in the European Painting), A FIZIKA, MATEMATIKA ÉS MŰVÉSZET TALÁLKOZÁSA AZ OKTATÁSBAN, KUTATÁSBAN (Meeting of Physics, Mathematics and Art in Education And Research), Nemzetközi konferencia magyarul tanító művésztanárok és szaktanárok számára (International Conference For Artist-Teachers And Science Teachers Teaching In Hungarian), szerk.: Juhász A., Tél T., ELTE, TTK, Marosvásárhely, 2012. augusztus 15-18., pp. 89.-96., Budapest, 2013. (ISBN 978-963-284-346-9).

Involve QR-code reader smart phones into physics teaching
Modern communication technics are part of our students' everyday life. About 90% of our primary school 8th form students have an internet connected smart phone.

The huge amount of information they can have access to, undoubtedly induces problems at schools but, at the same time offers new opportunities to teachers. The traditional work-dicipline of the school is about to relax.

It is well known that students not interested in physics often do not even take a look at their homework, do not turn to their manuals but they keep browsing on the net with their smart phones. They communicate with each other spending their time on searching for often unimportant information.

Instead of dissuation and interdiction, I consider it more promising to attract smart phones into teaching-learning process.
One of the possible ways to attain this, is to use the smart phone as an auxiliary device, respectively as a measuring gauge (when shooting high frequency videos (Argument 4.) I and my students used smart phones).
The other big opportunity is given by the communication features of the device. With the help of the QR–code, readable with the help of the phone, the user gets immediate access to the website given by the internet code.

Argument 6.

I have shown that using a smart phone-built-in QR-code reader it offers new opportunities in teacher-student communication. Thank to the QR-code, teachers'demonstrative possibilities expand. In order to make a presentation of a natural phenomenon, of a history experiment or of a new technical invention, theoretically any special material is at our disposal on the net.
Using the code given by the teacher, reading it, the student is able to get to the right website immediately. The QR-code makes not only public websites quickly accessible, but also such ''internal'' homepages, which have been edited by the teacher or teacher-teams aiming to support school activity directly.

Applying QR-code means new opportunities in tasks' assignment process. That would mean not exclusively electronically-given tasks, but also traditional paper-based task assignments, plus completing them with the help of the QR-code.

I made up paper-based exercise-sets for my students with QR-code support for the answers of some of the questions. This way videos, pictures, source materials and valuable applications could be attached to the exercises. QR-code makes efficient support of individual solving of exercises possible. Also, students, with the help of the QR-code, are able to check the results of the main steps of the exercise and, if it does not match with his/her own results, thank to an attached code, help can be asked for. Help can differ depending on the type of the problem. The method is similar to the 'programmed' problem solving, so popular in the 1960s, but it adds modern technics' opportunities.

My experience shows that QR-code exercises can very well be applied in team-work or in doing homework. Students enjoy using their smartphones to solve their exercises and to complete school material with QR-code suggested materials. I think it is an important success that more students have been doing their homework as before, including even those who had not even opened their manuals. Naturally, favourable approach of students was also due to the novelty character of the method. I suppose, however, that the advantages of the method, the speed and variety of communication, will make the method be useful in future education as well, when using QR-code becomes usual.

Psychological motivation to help learn physical phenomena

Cognitive psychology has proven that efficient studying does not mean acquring knowledge passively but conscious, interest motivated acceptance of those,
In my teaching activity I am continually looking for opportunities to arise and maintain students' interest on what is being taught.

It is well known that our attention strengthens whenever it is about any question that touches us individually. That is not only true on existential matters but also on bet-games or simple quizzes.

When we make a bet on the conclusion of something, we become interested in the matter and, therefore, we follow events more attentively. The same goes with the way viewers follow TV-quizzes. After questions have been asked viewers also think of a tip on the possible answer and even that internal standpoint results in a more attentive expectation towards the answer to come.

Argument 7.

Based on psychology of bets and quizzes I developed the 'Let's bet on Physics!' method which I have succesfully been applying in order to to motivate school class experiments and, also on public experimental presentations.

The essence of the method is that following the brief presentation of the problem, I ask listeners what they personally think of the result of the experiment and what their expectation is. In a good class community such a question is usually an opened one, meaning that everyone tells his/her opinion (While expressing standpoints, communication among students goes on, proper arguments become important and individual opinions get clearer. During discussion, teachers manage to get an insight into their students' way of thinking). In case of bigger audience, two possible answers that I offer, can be voted on by raising hands. After such introduction, the conclusion of the experiment and the explanation are expected with larger interest. And as far as my experience is concerned this is true even for those who have only given a 'blind tip' as an answer. Giving a tip they also become interested in what is happening.
The huge school class succes of the method made me reorganize my experimental presentations, based on the method, for larger audiences. I chose experiments that were proper for tip giving and their results had unexpected impact on most of the audience.
At the experimental presentations there was not only studying but fun as well. Many students who watched the experiments also thought to repeat them at home or in a friendly environment. As individual experiments done by students mean a great deal in making physics accepted, I have made a collection of experiments which can be conducted with simple devices. Those are harmless and spectacular at the same time and often give surprising results. Naturally, together with the experiments I also offer 'to give a bet on it' questions for people who like games. Humorous drawings are also added 'on a kind of comics manner', and illustrations support final explanations on phenomena as well.
Editing the exercises I tried the experiments out with my students, who presented them themselves to their colleagues. The publication of the collection is on its way.

Argument 7. Bibliography:

Stonawski T. Fogadjunk fizikára (Let's Bet On Physics), Mozaik….. (under publication)

Exploiting the achievements and new objectives

Students participating in the projects experienced that assertions published in the media or in press are not necessarily true and are not always well-grounded. They have realised that the technology and equipment surrounding them might be used not only for entertainment but – with adequate control – might be exploited as measuring appliances, and are suitable for assisting them in different school researches. The topics of the selected projects were always defined by specific school situations, and their abundance has not decreased to this day. Together with the students we have continuously recorded and published the results of the measurements, so we could experience the diversity and the excitement of scientific research. Owing to our joint work more and more students of Nagyecsed Lyceum have chosen Physics as one of the high school leaving exam subjects, which I consider a success. I have held several presentations on our more interesting topics to elementary and high school teachers nationwide, urging them to design similar projects.

I wish to keep up my work of proving or disproving assertions that have received media attention, with scientific methods high school students can use both at home and in school study circles under teacher control.

Henceforward I find it essential that I shall continue to report on our research activities to my fellow teachers in the form of articles and presentations, and I also intend to introduce practice-teachers to the results achieved and experience gained during my career as a teacher of Physics.