Enjoy physics classes with your own devices

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Abstract. Introducing the latest educational technology trends has accelerated enormously in the past few years; therefore, the use of personal devices, especially smart phones, tablets, laptops has increased considerably also in the educational processes. Many researchers used M-learning for different purposes (Hsu & Ching, 2013), but only a few of them used it for physics teaching experiments (Crompton, Burke, Gregory & Gräbe, 2016; Jarosievitz, 2016; Kuhn & Vogt, 2013). The use of M-learning devices in experiments is based on the rich set of built-in sensors in smart phones (Kuhn & Vogt 2013; Staacks, 2016). However, beside the devices themselves, also free applications and teachers’ (instructors’) expertise is required. In this work some meaningful use of M-learning during physics lectures will be presented. Some of the key terms describing the quality of the measurement have also been discussed with the students, and will be presented here. After the conclusion of the measurements, students used their own devices as clickers, and answered the questions synchronously and anonymously through an on-line assessment system.

1. Introduction
Based on the conclusions of my previous research activity made for my PhD study (Jarosievitz, 2005), and analysing different papers afterwards, it has become clear that the Physics education is in crisis in many parts of the world (OECD 2000, 2001, 2005; Sadowska & Kamińska 2010; Guido 2013; Grazier 2016).

It is a very interesting question why students do not like Physics, and how we can turn back their attitude in a positive way.

This crisis in Physics education is usually deepest in the primary and secondary sector. One of the causes of this crisis might be that in primary and secondary schools the number of Physics classes has been extremely decreased in several countries – also in Hungary. In parallel to this, the number of physics teachers has also decreased, so that those who are still working should teach 21-26 classes a week.

During the reduced number of hours the majority of the students cannot do any hands-on experiment, students became passive learners, they do not do experimental work during the classes, and therefore without experiments it is much harder to understand well the physics phenomena or topic.

Many good schools in Hungary are mainly concentrating only to problem solving during the Physics classes, do not let students do any experiments. The main reason is that the teachers teaching more than 21 classes per week, do not have enough time for setting up the experiments – even if they would have well-equipped laboratories, and they do not have technicians, who can help them with the preparation of the experiments.

In the 21st century the pure traditional physics classes are not good enough for attracting the students’ focus to the lectures. Many of the students may not enjoy the series of lessons (Turner 2015).
However, students have new tools in their hand, which can be used, and touching, doing something much more interactive attracts them better, instead of listening to the teacher’s explication.

The higher education level is not exempt of that crisis either, because of the decreased quality of the students leaving the secondary schools and entering in the university or college.

Some universities or colleges do not have students’ laboratories at all (at least here in Hungary), or the students’ laboratory (experimental) work is not included in their curricula (e.g: BSc in Engineering Information Technology).

Students studying in these places do not carry out any experimental work, and they are not familiar either with the measurements, or the key terms which describe the measurements’ quality. Students in these places are not involved at all in experiments (Jarosievitz 2011).

Qualitatively analysing some informal feedback of my students, I have found that the physics lectures should be made more colourful, attractive, interesting and interactive, especially in the first year of the university or college. Many researchers and teachers advised different methods and activities to increase the recognition of the Physics education (Bae & Kim 2013, Graham 2017).

Among these new trends the use of personal devices (BYOD), or other parallel interactive activities can be used, like Researcher’s Night (Jarosievitz 2012), Science on Stage Festivals http://www.science-on-stage.eu etc. Students using their own devices can take part interactively in the courses, and we do hope that accessing and sharing information with these mobile devices will motivate them, and will change their attitude towards science in a positive way.

If we let our students to leave the university or college without any skills in designing and performing hands-on experiments, they will become only theoretical professionals, and they will never be able to do any practical work, or inquiry based investigations.

We should not let our students to become digitally illiterate; therefore we must act immediately introducing using of different constructivist based methods (Grazier 2016).

2. M-learning devices used during the lecture
The definition of M-learning by Wexler: “any activity that allows individuals to be more productive when consuming, interacting with or creating information mediated through a compact portable digital device that the individual carries on a regular basis, has reliable connectivity and fits in a pocket or purse” (Wexler et al. 2008).

Seeing the difficulties mentioned in the introduction (e.g. lack of experimental work from curricula), I decided to introduce the use of innovation based experience of M-learning. I am aware that M-learning cannot replace authentic physics experiments, but they still can help students to predict and to explain physics phenomena, to calculate the accuracy, error, etc. They are also excellent tools for using cooperative learning, to work together in small groups on a structured activity, and for thinking first before acting.

This work has been done as part of a research program designed for first-year students in Physics at the Dennis Gabor College from Budapest, Hungary. This teaching experiment with mobile devices involved 188 students who were enrolled in my course.

At the outset of the course 43% of all 188 students (20.7% female; 79.3% male of them) filled in the general questionnaire (31 questions of different types) that was sent to them via the internal communication system. Only a few of selected questions and answers are presented in this paper, why the goal of this paper is not related to analysing the student’s attitude to their study. I made this study only to have some idea about the group involved in the experiment.

Analysing the responses of the students made before we started our lectures, I found their reactions that 24.4% are not really interested in using their own devices for physics measurements. 75.6% students answer, that they positively motivated to see some new ideas, implementation, and they looked forward to taking the measurements with their own devices.

I was also curious about what purposes the students used the new high-tech devices for, if they had one. Examining the responses I found that my students used their devices mostly for communication,
and my results are very similar to other results made in a completely different part of the world (Foti 2014).

Fig. 1. Portable devices used by students, for different purposes

3. Working hypothesis
“A working hypothesis is a hypothesis that is provisionally accepted as a basis for further research in the hope that a tenable theory will be produced, even if the hypothesis ultimately fails” (Wikipedia 2017).

Before starting my innovative pilot experience using portable devices (smart phones, tablets, laptops) for real physics experiments in Physics teaching classes, I have formulated the following working hypotheses:

Students turning to their neighbours and using their own devices will:
- find the physics lectures more enjoyable;
- be able to take different measurements;
- be able to discuss the measured values;
- increase their interest regarding to physics and the sciences,
- increase students’ problem solving and computational competencies, and also help to understand better the corresponding physics phenomena.

4. Real measurements done with personal devices

4.1. Aim of the Measurements
Here I present only two real measurements performed with portable (Android) mobile devices. The aim of both measurements was a classical one: to determine the value of the acceleration due to gravity without using the gravity sensor accelerometer of the device. Acceleration is quantified in the SI unit system by m/s².

4.2. Methods used for Activity
The experiment was performed with 36 students, who took part in the 3-hour lectures.
Before starting the activity first I grouped the students into informal cooperative, heterogeneous, learning groups (Brame & Biel 2015). Informal group-work consisted of the following:

4.2.1. Think-pair-share (T-P-S)
“T-P-S technique is designed to encourage students to share and discuss ideas around a particular topic, issue or problem” (Lyman 1981).
As “instructor of the group” I have given some instructions to my students and let them discuss and answer my questions formulated specially for them.

Questions
- If we measure the “$g$” value using different methods, what do you think, do we get exactly the same results as published already?
- Will the value of “$g$” be the same everywhere in the world?

First each student considered the questions, then they discussed in pairs, and finally changed their place and started to discuss their responses with other students from different groups. Every group shared their responses with all other participants.

The following Fig. 2 visualises the arrangement of the students in different working groups.

![Fig. 2. Examples of informal cooperative learning activities Think-pairs-share (adapted from Brame & Biel 2015)](image)

4.2.2. Peer instruction

Peer instruction is an evidence-based, interactive teaching method successfully pioneered and popularized by Harvard Professor Eric Mazur in the early 1990s (Mazur 1997).

The new technique known as peer-instruction can be used with and without technology (e.g., clickers). Peer Instruction encourages students to critically think through the arguments being developed, and to discuss their ideas with their neighbours.

This activity makes students better involved in their own learning, and focuses their attention on underlying concepts.

Since we did not have any clickers (special devices), my students used their own devices (tablet, smartphones, laptops).

Students answer different type of questions online, that means the students should use the network of the college, or university. This way the expensive “clickers” were replaced by M-learning devices, especially smart phones.

The main aim of the use of the Classroom Response Systems “Clickers” (CRS) was to promote active student engagement during a lecture, and promote discussion and collaboration among students.

All of my students got a QR code (with the direct link to the online poll: [http://www.socrative.com](http://www.socrative.com) and room number: f862bde5 used) already prepared in advance. Students first need to scan their QR code. If their device could not do it by default, they had to first download and setup an appropriate app into their own devices. As a first step students scanned the QR code and logged in as a students to the free online poll:

![Fig. 3. QR code prepared for students with direct link to the online poll](image)
Students without devices had to turn to their neighbours and discussed all questions and answers, before they voted in pair. Every answer was anonym and shared with all participants using the projector. This approach was well-received by all students.

Using the students’ own M-learning devices I got very good real-time information regarding their knowledge, while students shared their understanding by answering anonymously the formative assessment questions in a variety of formats: quizzes, quick question polls, exit tickets and space.

4.2.3. Jigsaw
Jigsaw is a method of organizing classroom activity that makes students dependent on each other to succeed. It breaks classes into groups.

Students work in a team of four to become “experts”. In our case each group of four students worked on the followings:
- setting up the experiment,
- take the measurements,
- work on data analysis,
- do the graphical representation of the measured values,
- prepare the final report,
- work on the conclusions,
- checking the validity of the hypothesis defined in the beginning.

Each student of each group became an “expert”. Then they changed their places and the whole class was rearranged, forming new groups, keeping one “expert” member from previous groups. The new group was informed and taught by the “expert” member. See Figs 4, 5.

![Fig. 4. Students became expert on the task that they were doing](image)

![Fig. 5. Rearranged class to allow peer-to-peer instructions](image)

4.3. The Real Measurements Done

4.3.1. Measurement 1
This measurement has been carried out with every small group, where one of the “experts” gave the instructions based on the previously described method.

One of the methods to determine “g” based on the observation of a falling ball in two dimensions (parabolic throw) is presented below. This measurement has been done with M-learning devices, with the new method (Juhász et al. 2015), instead of the usually employed free-fall (one-dimensional) methods.

For the first measurement we need the following materials: steel ball; ruler; laptop (equipped with a sound card) + microphone + projector; Audacity free program (software programs for sound recording) installed in the laptop (which can be downloaded from: [http://www.audacityteam.org/](http://www.audacityteam.org/) site.

(If we do not want to use a laptop and a microphone connected to the laptop, we can directly use our smart phone or tablet with a free app from Google play, called Audio Mix Studio. Using this app exactly the same measurement can be carried out, as can be done using a microphone and laptop. Ac-
tually students used their laptops for the measurements, while we shared our screens online with the audience. The laptop screen was projected to the observers.

After setting up the experiment, someone had to hit the steel ball which starts to move on the clean table. Group of the students, as observers followed the little steel ball motion, which was moving on the clean surface (table) and after a time it fell down, and hit the surface of the floor.

During the falling time we did not hear any sound. The sound file was recorded during the whole motion of the steel ball.

Students repeated the measurement 5 times, and then started to analyse the recorded sound file.

Examining the sound file each group was extremely curious to determine the exact time when we did not hear any sound. The period of time when we cannot hear any noise is actually the free fall time.

Finally, the recorded sound file was analysed and we also had to take into account the noise filtering of the recorded sound file. The recorded sound file of this experiment is plotted in the next figure (Fig. 5).

![Figure 6. Recorded sound file after the noise filtering](image)

From the definition we already know the free fall law

\[ h = \frac{1}{2} \cdot g \cdot t^2 \]

where \( t \) is the time of falling, \( h \) – height, \( g \) – acceleration due to gravity

From the law we can extract the \( g \) value, based by the time measured as:

\[ \Rightarrow g = \frac{2 \cdot h}{t^2} \]

For getting not only the value of the physical quantity but also the standard deviation, this measurement has been done 5 times. Analysing our result we got the following values (table 1).

| No. | \( h \) (m) | \( t \) (s) | \( t^2 \) (s) | \( g \) (m/s\(^2\)) | \( x_m \) (mean) | \( \Delta x \) | \( \delta x \) |
|-----|-------------|-------------|-------------|-----------------|----------------|-------------|-------------|
| 1   | 0.730       | 0.383       | 0.147       | 9.953           | 9.67           | 0.29        | 3.0%        |
| 2   | 0.730       | 0.386       | 0.149       | 9.799           | 9.67           | 0.29        | 3.0%        |
| 3   | 0.730       | 0.398       | 0.158       | 9.217           | 9.67           | 0.29        | 3.0%        |
| 4   | 0.730       | 0.393       | 0.154       | 9.453           | 9.67           | 0.29        | 3.0%        |
| 5   | 0.730       | 0.383       | 0.147       | 9.953           | 9.67           | 0.29        | 3.0%        |
| Average | 0.730       |            |             | 9.675           |                |             |             |
After a common – guided – discussion about the results the students conclude that our measurement gives the following estimation for the gravitational acceleration: $x_m - \Delta x < g < x_m + \Delta x$, which in this case gives $9.35 < g < 10.00$. They compare this result with the “known” value of the acceleration due to the gravity for our latitude: $9.81 \text{ m/s}^2$, and recognize, that this value is well inside the interval. This means to them that this measurement had probably no systematic error – the resulting value is “valid”.

“Validity: A measurement is ‘valid’ if it measures what it is supposed to be measuring. What is measured must also be relevant to the question being investigated” (http://practicalphysics.org/language-measurements.html).

Even this measurement has been done with their own devices, students confirm that they enjoyed taking these measurements very much, while they used their everyday devices, and understood the physics “with clicking and doing”.

They were very enthusiastic while being involved in this short part of the lecture, and carried out the task actively in each working groups.

4.3.2. Measurement 2

The second measurement had the same aim: to determine the value of the acceleration due to gravity ($g = 9.8 \text{ m/s}^2$) using another method. The aim of using another method was to show the students another possibility, other free program available, which can be used for physics measurements in case if they do not have a well-equipped laboratory behind.

For this measurement also the informal cooperative learning method was used. Some students set up the experiment, some of them recorded the video file of the action, some of them did the calculations, or wrote the report, and reported their results after some discussion with their neighbours.

Necessary materials used for the experiment were: handball (any large, well visible ball); ruler; smart phone or tablet; laptop; a free video analysis and modelling tool built on the Open Source program called Tracker (can be downloaded from: http://physlets.org/tracker site).

A very brief description of the measurement can also be found on: http://moodle.scientix.eu/course/view.php?id=179 site created by Carlos Cunha, which impressed me a lot. I decided to adapt it to my course in this pilot experiment with some minor changes and additional goals.

Students started the activity and made the “measurement”: $y = ax^2 + bx + c$ they recorded the motion of the falling ball 5 times. After recording the movements, the harder work started which involved transferring the data to the laptop, and starting the video analysis of each file. The video analysis took longer time, because the program was not a familiar tool used by the students before. In the beginning of the evaluation they had to learn step by step what they should do. The distance-time function of the falling ball is a quadratic function, and the value of “$g$” should be extracted from this function. The general form of a quadratic function:

For the free fall we have parabolic functions: $y = -\frac{g}{2} t^2 + v_0 \cdot t + y_0$

$a = -\frac{g}{2} \quad \Rightarrow \quad g = -2 \cdot a$
Table 2. Result after the measurements

| Files                          | a   | g (m/s²) | $x_m$ (mean) | $(\Delta x)$ (st. dev.) | $\delta x$ |
|-------------------------------|-----|----------|--------------|-------------------------|-----------|
| 20160311_123159.mp4           | 4.63| 9.26     | 9.33         | 0.07                    | 1%        |
| 20160311_123217.mp4           | 4.62| 9.24     |              |                         |           |
| 20160311_123235.mp4           | 4.72| 9.44     |              |                         |           |
| 20160311_123253.mp4           | 4.67| 9.34     |              |                         |           |
| 20160311_123316.mp4           | 4.69| 9.38     |              |                         |           |

where $x_m = \frac{\sum x_i}{n}$, $(\Delta x)^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x - x_m)^2$, $\delta x = \left(\frac{\Delta x}{x_m}\right)\times 100$

After discussing the result the students conclude that our measurement gives the following estimation for the gravitational acceleration: $x_m - \Delta x < g < x_m + \Delta x$, which in this case gives $9.25 < g < 9.42$. Here they also compare the results with the “known” acceleration due to gravity value, and realize that. In this case the value lies well outside the limits defined by this measurement $(9.33 \pm 0.083$ m/s²). The relative deviation from the generally accepted value is about 5%, whereas our statistical fluctuation is only about 1%. This gives us the opportunity to discuss the possible causes with the students. Here we have the opportunity to mention that according to the probability theory the one-sigma interval contains only about 67% of the measured values. Therefore there is still a substantial probability (about 33%) that the “real” value is outside the one-sigma interval. However, the generally accepted gravitational acceleration is even outside the $x_m \pm 3\cdot \Delta x$ interval (three-sigma interval), and the statistical probability of that should be less than 1%. Therefore we can conclude that this measurement definitely had also some (~ 5%) systematic error: either the “picking” of the exact positions of the ball is not precise enough, since the ball is an extended object, and – additionally – the image of the ball gets more and more blurred as the ball moves faster and faster, making the position-picking more and more difficult and less and less precise, or there is a small timely deviation in the frame rate of the video.

The discussion of these discrepancies was also very informative and useful for the students, since they got a more practical feeling what was the difference between a systematic error and a statistical error.

5. Conclusion

Making anonymous personal interviews with my students, I could conclude that students who participated in these lectures enjoyed very much the use of informal cooperative learning method. They really liked to cooperate with their neighbours “Turn To Your Neighbours” (Mazur 1997).

They felt it was very useful, and it motivated them more to carry out their tasks, to do calculations and to answer the questions.

They also very much liked the idea of bringing and using their M-learning devices to the lecture. Finally they felt that they were better prepared for physics exam, while they had been involved in the measurements. They also understood better the corresponding physics phenomena and laws, while they became active learners during the lectures, and not only passive listeners. M-learning is very useful for learning, for reading and finding relevant content on the Internet, for assessing acquired knowledge and for performing real measurements, therefore it should be implemented much more in higher education activities not only in a pilot experiment.

By making more measurements with M-learning devices one can study much better the students’ attitude to physics, and can influence them to increase their motivation and solve problems interactively in cooperation with each other’s.
For me it became clear that if we use only the same old strategies, methods and techniques we will never challenge our students’, the Z generation’s attitude. By using different methods, this pilot activity looks promising to shift the role of the teacher, and to increase the audience activity. 

„The future cannot be predicted, but the future should be invented” (Dennis Gabor).

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