PHYSICS TEACHING ACTIVITIES AND RESOURCES USED INNOVATIVELY IN HIGHER EDUCATION

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1. ABSTRACT

Different types of activities and resources are very useful for improving the main core competencies (researching, questioning, critical thinking, problem solving, decision making, and computational competencies) of our students.

The use of own M-learning devices for different reasons like reading, finding relevant content on the Internet, and also for performing real measurements, multimedia and its applications, video files and simulation programs can also change our students' attitude to science subjects, especially Physics [1; 2].

The rich set of built-in sensors in the smart phones represent an excellent opportunity for using the own devices in physics experiments [3]. If we want to let our students leave universities with an adequate knowledge and with applicable skills in physics, we should take the advantage of the ICT, multimedia and M-learning devices (laptops, smart phones, tablets) and their applications [4; 5; 6].

The activities and resources presented in the paper have been developed and tested with students enrolled to Physics course who are studying for BSc in Computer (IT) Engineering or BA in Business Administration and Management. Students enrolled in the course have brought their personally owned devices (laptops, tablets, and smart phones) and used them for the activities described in this paper.

I do hope that these activities will positively change the students' attitude to physics, and they will be much closer to everyday life.

2. INTRODUCTION

Based on my previous research and comparing many new reviewed papers written by different researchers, it has become clear that education of natural sciences, especially in the primary and secondary schools, is still in crisis in many parts of the world [7; 8; 9].

Analyzing one of the papers published by Ryan, M. D.G., based on an investigation of 446 engineering and technology students, I have found that most of the students did not enjoy learning physics mainly because they did not like their professor [10]. Some other personal interviews also confirmed this statement in another region, where no survey has been lunched.

"Yet today, there are emerging concerns about Physics education: Secondary school interest in Physics is falling, as is the number of Physics school teachers. There is clearly a crisis in physics education; recent research has identified principal factors" [i].

"Kids don't like physics and maths". Young people "see STEM (science, technology, engineering, and mathematics) as a career dead-end" [ii]. These statements are shocking, and they are completely in contradiction with other views that explain that STEM careers have big prospective.

Many of the STEM occupations are predicted to grow up between 2012 and 2022. Therefore STEM workers should have a combination of skills, main core competencies and experiences for starting in these careers [iii]. STEM has not a universally agreed definition. "Experts generally do agree that STEM workers use their knowledge of science, technology, engineering, or math to try to understand how the world works and to solve problems. Their work often involves the use of computers and other tools." [iii].

Core competency is a concept in management theory introduced by, Prahalad, C.K. et al, which can be defined as “a harmonized combination of multiple resources and skills” [11; 12].

We are all aware that there is a big crisis in education, and especially in physics education. This crisis is the deepest in the primary and secondary sector, but also higher education has problems. This latter is mainly because of the decreased quality of the students leaving the secondary schools and entering in the university or college. The traditional physics classes are not good enough for attracting the students’ focus to the lectures. Many of the students may not enjoy our lessons or series of lessons [iv]. Many of the students do not take part in lessons. Globalization and technological change processes have accelerated enormously in the past few years; therefore the use of personal devices, especially smart phones, tablets, laptops (BYOD) has increased considerably also in the educational processes [iv].

Bring Your Own Device (BYOD) has many different definitions. Actually the term of BYOD started getting used commonly only in 2009. The movement of BYOD has received a lot of attention in recent years. Bring Your Own Device means bring your own technology, your phone, your Personal Computer and use those devices to access information, applications, etc. BYOD has become one of the dominant models in educational settings at all levels. “Putting technology in students’ hands is transforming the educational experience, not only in colleges and universities, but in K-12 schools as well. BYOD is fueling the transition as educators move from traditional lecture-based instruction to new models of learning, teaching and collaboration” [v].

Many teachers, researchers used their devices; mobile learning for different purposes, but only a few of them used it for physics teaching experiments, or online assessments. Mobile learning (M-learning) is education via the Internet or network using personal mobile devices (tablets, smartphones). Via those devices students can obtain learning materials through mobile apps, social interactions and online educational hubs. M-learning is flexible, students can access education materials interactively anywhere, anytime. Mobile learning provides a way for educational institutions to deliver knowledge and educational content to students on any platform, any place and at the time of need. Students can use their mobile devices, required apps and tools to complete and upload assignments to teachers, download course instruction and to complete tasks [vi]; [vii]. Many of the students have their devices, but they are not familiar how to use them for study. We should encourage and teach our students to use their devices for good purposes.

Since the popularity of physics has decreased we are all curious what should be changed to motivate our students better: the methods, the content of the subject, the use of the devices, etc.

Summarized: many teachers are searching to find different methods (lecture, demonstration, collaboration, classroom discussion, peer instruction (flipped classroom) [13; 14, 15], etc.) or different physics teaching activities to reach the main goal: to increase student’s motivation, and get physics into the mainstream (eg.: TV show, role models) to increase the connection between physics and daily life, supported by institutes, labs and industry.

Analyzing different approaches I can conclude and recommend to act immediately in the hope that if we act, we can save the new growing up generation from becoming digitally and scientifically illiterate [16]. We should do all our efforts to increase students’ interest in pursuing Science, Technology, Engineering and Mathematics Studies and Careers (STEM).

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” [viii].

Before starting my innovative experience used in Physics teaching classes, I have formulated the following working hypotheses:

- interactive activities (real experiments presented) make physics education more effective,
- showing video experiments (only when we do not have the experimental tool) improves students understanding of the corresponding physics phenomena,
- ICT (e.g. using simulation programs when we do not have laboratory background) increases students’ problem solving and computational competencies, and also help to understand better the corresponding physics phenomena
- using of the own devices (BYOD) is more attractive to students,
- interactive classes, using students own devices increase the lectures’ attendances, students become more motivated.

4. METHODS USED FOR ACTIVITY

During my BSc Physics courses I have used the following innovative teaching methods, based on the constructivism, in combination with the traditional university lecture:

- lecture (approximately 80%),
- demonstration of the real experiments (20%, while we did not have experimental setup, and lab behind),
- collaboration work (20%),
- classroom discussion (20%),
- peer instruction (flipped classroom) (25%).

(The sum of these fractions is more than 100% since they are not mutually exclusive teaching methods.)

I have used each of the methods when I taught some parts of the subjects. Not every method has been used in every lectures (occasions), because we know that every method has advantages and disadvantages.

Traditional lecturing is one of the traditional ways of teaching physics. Since most teachers are taught by this method they continue to use this method in spite of many limitations as it is very much convenient especially for big number of students in a class. This method is teacher centric; the teacher has the main role. In some cases, like introduction of a new material (for example: the structure of atoms, the concept of the atomic number and mass number), or explaining a new phenomenon the method can be applied well.

On the other hand, the use of this method is really ineffective in developing critical thinking and scientific attitude among students. Using the traditional frontal lecture transmission method, or demonstration, students often leave the room with no impact and no idea about what was going on during the course. Sometimes they do not even remember the topic discussed in the lecture. On the other hand there are new styles of teaching coming soon even in the higher education [ix].

Using new learning methods (collaboration, classroom discussion, peer instruction) students can be kept active by the teachers and will think and learn during the courses together with the teacher's explanation. Everybody from the audience will leave the lecture room with some impression about the topic heard on the lecture, and start processing their thoughts afterwards.

5. USE OF ICT, MULTIMEDIA

The origin of the internet in Hungary has its origins in 1988 when the Hungarian Academic and Research Network HUNGARNET was created. Hungary was allowed to connect to the public Internet in 1991. An internet program for Hungary's secondary schools, named SULINET (Schoolnet), was launched in 1996, under the auspices of the Ministry of Culture and Education. The program has been approved by the Hungarian Parliament [x].

The use of ICT gradually became a common requirement in education. The effective spread of the use of Information and Communication Technology (ICT) in Hungary has been started in 1998. From 1998 many teachers improved their computer competencies, and have tried to embed ICT in their daily teaching activity.

The use of ICT in science, particularly in physics education in Hungary started "experimentally" at the same time as in the US, or in the countries of Western Europe. Some of the physics teachers started to use microcomputers in science education, or they have demonstrated some physics phenomena with computer modelling, and using simulations. Many good resources have been developed in the early nineties [17 - 23].

Unfortunately nowadays some teachers are still worried to use the new technology and do not make enough efforts to improve their knowledge. We have many possibilities to use the new technologies around us, but we should focus more on the question how to use them for increasing the students' motivation. We have the tools, but maybe we are not prepared enough.

The effective integration of ICT into the educational system is a very complex process, which involves the followings: curriculum and pedagogy, institutional readiness, teacher competencies, and long-term financing, among others.

5.1. Simulations used in Physics course

During my educational activity I have found that it is hard to adequately teach some parts of physics without experiments, or without the use of computers, multimedia and its applications. This is especially true for introductory courses, where motivating the students is very important. Sometimes we do not have dangerous materials or equipment available in the laboratories or classrooms; in these cases we should use the pre-recorded video files or simulation programs.

A computer simulation is a model of real-life or a hypothetical situation on a computer. By changing variables in the simulation, predictions may be made about the behavior of the system. Computer simulation programs offer a unique opportunity for students to see and work with systems and substances that they would rarely, if ever, be able to actually practice with in reality.

Dangerous substances and situations, expensive equipment, and theoretical, even fantastical ideas can be explored in a way that is more thorough than practical teaching has ever been able to do before. Never before has there been a situation in which the creative mind can be so safely and precisely indulged in this most important area of education.

These benefits of computer simulation programs must not be misunderstood to mean that a computer can be the sole provider of instruction for students of physics and natural sciences; nothing can replace a good physics teacher and real experiments!

The use of simulations has many advantages. Using simulations dangerous experiments can be reconstructed, and running the simulation physics phenomena can easily be explained.

Because there was no laboratory available, during my course I used some parts from the previously prepared online courses: http://www.sukjaro.eu/cikkek/cikkek.htm. These e-learning courses have been prepared for teachers, lecturers, or for students (high school and BSc level) who study individually or with the help of the teacher or tutor.

Each course includes gamification and group-work activities, contains students' and teachers' guides and self-evaluation tools, like multiple choice questions, interactive exercises with simulation, theoretical exercises etc. These courses can be evaluated individually or in groups. During the evaluation the following methods can be used: lecturing, collaborating, classroom discussion, inquiry-based learning. All of these courses are related to study the properties of the radioactivity: the random behaviour, the exponential decay law, notions of half-life, decay constant and activity. The use of these courses requires core competencies in ICT.

5.2. ICT based activities used during the courses

Use of PADLET

Sometimes for classroom discussion I have used another ICT based application during my course, called: Padlet: https://padlet.com/. This free online Internet based application allows users to express their thoughts easily on a common topic. Padlet can be used also like a digital canvas, where beautiful questions can be created, which can be shared. Students getting this link can read the raised up questions and can express their opinion online; they can develop their communication skills while discussing the hot topics. This platform works like a piece of paper, used for brainstorming.

5.2.1. Use of LearningApps

LearningApps: https://learningapps.org is a Web 2.0 application created to support learning and teaching processes with small interactive modules. This application can be used on students' own devices [16; 24] for learning and for self-study especially for self-assessment.

The aim of this application is to collect reusable building blocks and make them available to everyone. Blocks (called Apps) are not suitable as complete lessons or tasks, therefore they should be embedded in a lecture, part of the teachers explication.

During my courses I have embedded some of the blocks in my courses, when I was curious to test my students' knowledge from a previously discussed chapter. This activity did not take more than 10 minutes, used as a review of previous material, and warming up activity, preparation of the new topic discussion.

5.2.2. Use of Quizlet

Another ICT based online free tool used during my course is called: Quizlet: https://quizlet.com. This app can also be used for learning by studying with flashcards, games etc. It is a simple tool used for powerful way to study. Students can run the application on their own Android devices. I used this tool embedded in the physics course as review of each chapter from the topic discussed before. This tool requires the same ICT based experiences from students and teacher.

5.2.3. Use of Video based experiments

Many dangerous experiments cannot be presented during the course, because we do not have respective materials, or experimental equipment. During my course I have not got physics laboratory behind, I was not able to show any atomic physics experiments to my students. Since physics is a natural science, I think that physics subjects should be taught with experiments. Therefore, if no laboratory is available some pre-recorded experiments can be shown for students using different scientific video channels, or preregistered films. Educational video used during lectures has transformed the engagement levels of students and has created a greatly enhanced learning experience. Students where more alert motivated and focused on the topic at hand.

One of my favourite experiments is to show how chain reaction works. First I used to present the simulation of the phenomena using this site: https://phet.colorado.edu/en/simulation/nuclear-fission.

On the other hand I also showed my students a chain reaction modelled with an experiment, which has been previously recorded. Here the advantage of multimedia, video has a major role during the course. The recorded experiment can be seen here:
https://www.youtube.com/watch?v=HsIxVhucqI0&feature=youtu.be.

Based on my experience and on students' reports given me in informal private talks, I conclude, that for some of the physics content the use of simulation programs and video resources greatly enhance the effectiveness of the teaching. E.g. in this case students will better understand the importance and the advantage of the chain reaction. We have a major role as teachers that we should help our students to learn the basic nuclear concepts. I am sure that if they have enough knowledge they will not be afraid e.g. from Nuclear Power Plants, and they will be familiar with the new investigations around us.

6. M-LEARNING DEVICES USED IN HIGHER EDUCATION

M-learning can be used in very different ways, it 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.

The following activities and resources have been developed and tested with students enrolled to Physics course during the school year 2015/16 and 2016/17.

6.1. M-learning devices used for assessment

Motivated by research done by Eric Mazur's [13] I have decided to introduce the use of M-learning devices for making physics significantly more accessible to my students. Since we did not have any dedicated clickers, my students used their own devices (tablet, smart phones, and laptops) during some courses.

All students got a piece of paper with a QR code (with the direct link to real-time questioning tool: http://www.socrative.com created by me and the room number). For QR code scanning the free downloadable apps from Google Play, e.g.: QR Droid has been used.

During the 45 hours of lectures and seminars, 5 different surveys have been filled out (10 questions/each test). Each of the questions was related to the physics phenomena or law taught previously. During each lecture students brought their own devices (BYOD) and filled in the online surveys, clicking on their devices' screen (tablet, smart phone). Students without devices had to turn to their neighbours with a device, and discussed all questions and answers, before they voted together. I have focused on collaboration method and class discussions. Every answer was projected to all participants anonymously. I have asked different questions from my students. See some of them:

Sample questions:

- Which statement is true for a perfectly inelastic collision?
  a) only the total momentum is conserved
  b) only the mechanical energy is conserved
  c) both the total momentum and the mechanical energy are conserved
  d) none of the momentum and the mechanical energy is conserved

Only a few of the participating students gave the right answer, which I found strange. Examining the causes why they did not know the right answer, I concluded the following: probably they were not preparing and reviewing the taught material from lesson to lesson, they prepare themselves only for exams.

The results for some other sample questions show that student are not used to connect physics phenomena to everyday life, therefore they usually "just click", choose one of the answers almost randomly, without some thinking.

- A compressed spring is placed between two trolleys of masses 200 g and 400 g respectively. They are in equilibrium at this stage. When the spring is released, the 200 g trolley starts moving with a speed of 6 m/s. At what speed will move the other trolley?
  a) 1 m / s
  b) 2 m / s
  c) 3 m / s
  d) 6 m / s

This question has been answered mainly correctly. I have got more than 50 % of good answers.

The answers of the next question show that the knowledge acquired in primary school should be taught again at least for a large portion of the students. The students had to learn the SI system units in primary school, but in spite of that only a few persons answered correctly the following question:

- In which group are units of the SI system exclusively?
  a) kg, s, oC, m, V
  b) g, s, K, m, A
  c) kg, A, m, K, s
  d) g, s, cm, A, oC

Many other different questions have been used for this research activity, and the origin of the right and bad answers has also been studied.

Summarized: I am confident that this method gets students better involved in their own learning and focuses their attention on the underlying concepts This approach was well-received by students. Using the students' own M-learning devices I got very good real-time information about 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 [25].

My opinion is that we should let students use their own devices at more lectures. We are confident that students' attitude to learning and doing in the last few years has been changed a lot. Students attend the lectures, seminars and workshops more enthusiastic if they are motivated, if they are attracted, or if they enjoy the differences that the new technology devices offer as compared to a book or a paper.

6.2. M-learning devices used for measurements

During my course two real measurements have been 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.

One of the methods presented here was to determine "g" based on the observation of a falling ball in two dimensions (parabolic throw). This measurement has been done with M-learning devices, with the new method [26] instead of the usually employed free-fall (one-dimensional) methods.

For the first planned 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/ site).

Actually we used our laptop for the measurements, while we wanted to share our screen online with the audience. Our laptop screen was projected to the students.

After setting up the experiment, someone had to hit the steel ball which starts to move on the clean table. 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 we had to determine the exact duration of the time period when we did not hear any sound, which was exactly the free fall time.

Students very much enjoyed performing these measurements, while they used their everyday devices, and understood the physics "with clicking and doing". They were very enthusiastic while being involved in the lecture, and carried out the task actively. They improved their researching, questioning, critical thinking, problem solving, decision making, mathematical and computational competencies a lot. There are many other measurements already published by different authors which can be adapted [27].

7. CONCLUSIONS

Making anonymous personal interviews with my students I could conclude that students who participated in these lectures enjoyed physics much better than they did before in their previous study. Students also liked very much the idea to "turn to their neighbours" and "use their own devices". Students who join my courses felt the use of ICT embedded in the courses very useful. Finally they felt that they were better prepared, while they had been involved in the measurements, and they also understood much better the corresponding physics phenomena and laws, while they became active learners during the lectures, not only passive listeners. Students' attitude was also improved when students were actively participating in discussions with their peers, as opposed to being passive or working independently.

Summarising: the following main conclusions confirm the working hypotheses defined in the beginning of this innovation experience

- interactive activities make physics education more effective,
- showing video experiments students will understand better the corresponding physics phenomena,
- using the advantages of ICT the students' problem solving and computational competencies have been increased,
- using students' own devices (BYOD) innovative techniques have been used, which keep students engaged and motivated,
- having interactive classes the lectures' attendance has been increased.

Students of the 21st century need digital skills to leave the universities with an adequate knowledge. This is necessary for finding and keeping a good job. Therefore combining traditional methods with active learning and the use of videos during the lectures will more and more increase their attention in the digital world. Nowadays all top jobs require digital skills, the understanding how the digital world works around us or how to manage basic processes from home, or how to be in competition with others at international level. All these activities based on ICT increased students' academic knowledge and their core competencies.

It is my hope that we can make the physics lectures more attractive and understandable to more students with the help of the use of own devices, ICT and specific pedagogical instructions.

"There's no doubt that the face of modern lecturing is undergoing significant change, and with the net generation as the main audience it is vital that lecturing moves with the times and adopts more innovative techniques to keep students engaged and motivated" [xi].

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