HOW TO MERGE TECHNOLOGY WITH METHODOLOGY IN MATHEMATICS AND SCIENCE EDUCATION – THE GEOMATECH PROJECT

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ABSTRACT

The GEOMATECH Programme is a large-scale EU funded project which aims to develop high-quality teaching and learning materials for all grades in primary and secondary schools in Hungary. These materials (1200+ Mathematics, 600+ Science) will be embedded into an on-line communication and collaboration environment. The portal is to be used as an electronic textbook, a homework system, and a virtual classroom environment. In this paper we present the details of the Project and give some examples how to use it in the classroom.

INTRODUCTION

Looking around the world there is no question that technology turns into the essential part of the everyday life. A proper combination of pedagogical methods and cutting-edge technology must be, therefore, the primary goal for the education system at all levels. As one might expect, the successful integration of technology into mathematics and science education depends on several factors. It is also evident that the teacher plays the most important role in this process. That is, no essential change can be done only by integrating new technologies into science education. Teachers' preparation and motivation is indispensable. Moreover, as Hennessy and Osborne [1] state, teachers have to be responsible for evaluating appropriate technical resources and designing the learning activities.

Several large-scale projects around the world [Argentina, Thailand, Uruguay, USA] attempted to hand out millions of laptops and/or tablets to students. However, various studies pointed out that these actions only are not enough to have a breakthrough in science and mathematics education. Parallel to the integration of the novel technology, a training is also needed for teachers in order to be able to use new devices in their everyday practice [2,3].

Luckily, we had the opportunity to develop a programme called GEOMATECH. It was funded by the EU and the Hungarian Development Agency to integrate the STEM (Science, Technology, Engineering, and Math) subjects and digital technologies based on an open-access web portal [4]. The basic purpose of this short paper is to present the main ideas and the novelty of the GEOMATECH Project.

PROJECT OVERVIEW

There is a consensus probably not only in the teacher community but also among the parents, policy makers and students that the mathematical and science education needs refreshment. Looking at our children there is no doubt that they are "digital addicts". To reach any success in their education we cannot ignore this fact. The GEOMATECH Project serves professional and peer-reviewed digital materials that can be connected to the everyday-used electric devices.

The basic idea of the Project is to develop 1800 digital materials (1200 mathematics and 600 science) for all grades in primary and secondary schools. These materials are embedded into an on-line communication and collaboration environment that can be used as an electronic textbook, a homework system, or a virtual classroom. An important feature of the portal is that beside the teachers and students the parents might also have an access to the materials and, thus, they can follow the educational progression continuously.

During the realization of the Programme six different groups worked closely together. In what follows, we summarize the main tasks of these groups in order to give an insight on what segments were synthesized to build up the GEOMATECH Portal.

- Material development: This part of the Project brought together traditional pedagogies and new curricula in order to have more efficient methods
- Software development: For better visualization and supporting the physical experiments GeoGebra [5] got several new features. The 3D part of the software become more versatile. The real-time data collection is already a default built-in function. It means that various software (e.g. Tracker) and/or hardware (mobile phones, data capture devices) can be connected to the GeoGebra software and use it in data acquisition and reduction. An android application has also been developed in order to make the physical experiments more accessible to students.
- Piloting: 25 mathematics and 20 science teachers were involved into the pilot study. The main purpose of this program was to get valuable feedback from those teachers and students who already used the GEOMATECH in their classrooms. The information collected in this work was extraordinarily important not only from theoretical point of view but also in practical sense for other parts of the Project.
- Teacher training: A total of 2400 mathematics and science teachers were involved nation-wide in this part of the Project. We offered a 60-hours training with innovative curriculum that fully matched the basic objective of the Project. During the training teachers learnt the basics of the GeoGebra software, modern methods in education, use of the GEOMATECH portal, WEB2 techniques, file sharing, mobile phones in science courses, etc.
- Student competitions: Multi-round competitions were also part of the Project. A large number of teams (more than 200) joint these cheerful events every month. More than 1000 students from all grades solved the interesting mathematics and science exercises based on GeoGebra.
- Teacher community: After the Project was completed, a very important issue was the information sharing between teachers who participated the Programme. Therefore, an on-line site has been created which offers a common platform to discuss the experiences, to share new and innovative ideas, or just think together about the possible further applications offered by the Programme.

About 200 people were directly involved in the Project. The next section is devoted to the results of their contribution.

MAKING USE OF GEOMATECH

First we want to emphasise that GEOMATECH is meant to be not only a collection of digital materials but rather a platform that includes all the methods we use in classes or, in general, the possible ICTs (Information and Communication Technologies) that are used in mathematics and science education. In this section we present some applications and methods of GEOMATECH.

GeoGebra. All digital materials in GEOMATECH Portal are based on the dynamic mathematics software GeoGebra [5] developed by Marcus Hochenwarter in 2001. The software is basically designed for elementary and secondary school teachers and students in order to clarify the abstract mathematical concepts and methods. In the last 15 years the software became one of the most common mathematical software around the world. It is completely free and open source. Thanks to the continuous developing nowadays GeoGebra can be used on-line on several different platforms (PC – Mac, Linux, Win; Tablets, smart phones – Android, IOS) and also various features for STEM subjects are built in. Last but not least, in the last decade, Hochenwarter and his team established a world-wide community including the GeoGebra tube, a collection of more than 200,000 public materials. In addition, the International GeoGebra Institute brings together more than 150 local GeoGebra Institutes in all five continents.

What to teach and how to teach? No matter what kind of class we want to give, the basic aims of GEOMATECH suggest to use at least one computer and a projector. Therefore, the teacher must be familiar with using such devices. The same is also true in the case of team-work or a class in a computer room (e.g. we should take care that the appropriate number of laptops are available or consult to the system administrator about possible experiments in a computer room).

We can decide what portion of a class is going to be covered by GEOMATECH. One possibility is to present just a few materials while introducing a new topic. The other choice can be a chain of materials (related to the same subject) at various parts of the course. Furthermore, digital materials can be used during the entire 45 minutes. This latter is quite easy, since, as mentioned above, the materials are based on GeoGebra and, therefore, the students can be strongly involved into the work. So, they should not just be watching the canvas but doing something profitable on their machines. In other situations, say, exams and/or homework GEOMATECH can also be utilized.

The GEOMATECH materials are essentially designed for visualization and for redeeming certain experiments. However, in fact, they do not replace the equipment in the physics laboratory. Next, we classify the digital science materials.

The first class contains "computer simulations" of easy demonstrations. These applications are more or less the same as we can present in a classroom but, of course, they cannot replace the original experiments (for example, harmonic oscillations, conservation of angular momentum, Lorentz force in fluids, etc.). Nevertheless, we can argue in favour. These "experiments" can be repeated any time with several different parameters. Moreover, students can take them home and play with them. (This is true for the other two groups below as well.)

The second class includes materials that are related to experiments difficult to present (due to the available time or space) or impossible to make because no components are accessible in the laboratory, e.g. complex electric circuits, elaborated optical arrangements.

In third group one can find materials which describe physical processes/experiments that are unworkable (due to the timescales or measures) in a classroom. For instance materials in atomic physics, environmental flows, astronomy, etc. Simulations like these might help to draw students' attention to the less graphic experiments or to the hot topics of modern scientific problems.

Methods and materials resulting in more interesting and impressive in-class experiments. The most challenging task in the 21st century education is probably to keep pace with the fast improving digital technology and to give valuable and usable knowledge to the students. Teachers play an important role in creating motivation. It cannot be done only by knowledge transfer. Using the current available technology is also necessary. Therefore, it is extremely important that teachers should be able to use ICT during their classes, and not just for presentation. These days the IT is already not about ppt presentations only, but much more.

Teaching science is unimaginable without measurements and demonstrations either for teachers or for the students. It is clear that students remember a mathematical function describing a natural phenomenon better if the measurements are done by themselves. It also does matter what kind of devices they use. The motivation can be missing if the students feel that the equipment around them left back from long ago.

Smartphones take over the mobile market. One can buy a smartphone roughly for the same price as a classical mobile. Another important fact is that the cheapest smartphones are as good as the most expensive devices in the sense of classroom use. In other words, all students can have the same potential to perform physical measurements during the science courses.

But what actually a smartphone means? A loose definition might be: a device that runs an operating system (OS) independent of the hardware used. A second important criterion is that the manufacturer of the OS offers an on-line application store and the owner can download various programs from this market to customize her/his smartphone. Moreover, having the suitable programming skills, people can also write such applications.

Another remarkable phenomenon of smartphones is that they contain various sensors. By using these sensors one can broaden the applicability of the phone. For example, by putting the phone face down the silent mode is activated, or by firmly shaking the device an incoming call can be rejected. Several years ago innovative physics teachers already involved smartphones into science education. [6,7,8] The GEOMATECH offers a professional way to use the mobile sensors as innovative applications in physics classes.

In what follows, we will present a possible use of the mobile phone for data mining and real-time data processing. Using the sensors and the mathematical skills of the GeoGebra software together the students might have complex digital measuring equipment in their hand.

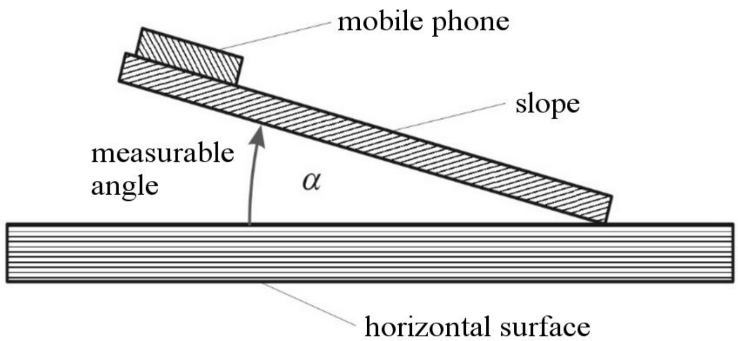

Fig.1. Using a smartphone in an experiment to determine the static friction between two different surfaces

Fig.1. depicts the experimental design for measuring the static friction using mobile sensors. We need a surface with alterable slope, a smartphone, and the Geomatech Sensors application from the Google Play store. For more details how to download and set up the program (and other requirements) please visit the website [9]. In addition, one can prepare

various boxes with different kinds of surface to measure the material dependence of friction. In this experiment the varying quantity is the angle alpha. The smartphone application tells us the acceleration of the phone for each value of the inclination of the slope.

Fig.2. shows the GEOMATECH material related to this experiment. On the upper part of the screen several questions can be found related to the experiment. For example: "*Sometimes the objects do not slide on the slope. What is the reason? What kind of force keeps the smartphone in place? What is the angle when the object starts to move? What physical parameter can be obtained from this tilt?"* The main window shows the GeoGebra application with four buttons (start, stop, new measurement, and data evaluation). In order to connect the smartphone sensors and perform the actual measurement a code is required. This code is generated by the Geomatech Sensors application and should be typed into the text-box. The co-ordinate system depicts the gradient vs. time. From the graph the angle can be obtained when the mobile phone starts to move. (In this plot the acceleration is not shown.) The experiment can be repeated using different materials between the phone and the slope.

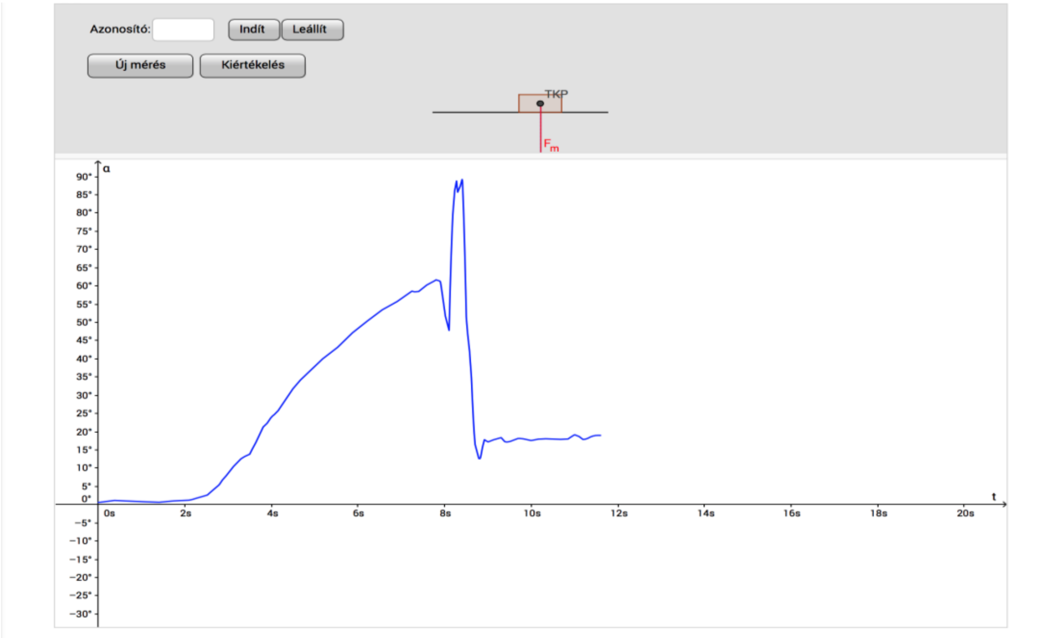

Fig.2. Real time data plot with GeoGebra and Geomatech Sensors

CONCLUSIONS

The GEOMATECH Project, i.e. the material and software development, the teacher training, etc., finished in September 2015. It is too early to assess the impact of this package on the science education at the elementary and secondary levels. The success of the Project depends on many factors. Nevertheless, taking into account the results of the pilot program, the feedback of the teachers' who participated in the trainings, and the positive media communication, it seems that the idea has a great number of potentials. We will see where the GEOMATECH evolves over the next few years and how it influences the mathematics and science education at the elementary and secondary school levels.

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