I. INQUIRY BASED SCIENCE EDUCATION

BRINGING SPACE SCIENCE TO LIFE WITH MOBILE APPS, SPACE AGENCIES AND HOLLYWOOD

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ABSTRACT

Some media for teaching space science and astronomy are introduced to show how they can provide a hook for gaining interest as well as providing authentic physics instruction. Four specific examples are chosen: smartphone star-gazing, the use of European Space Agency earth-monitoring satellite data, NASA exoplanet exploration and clips from some recent Hollywood films.

INTRODUCTION

Astronomy and Space Science sit on the edge of many Physics curricula, an option rather than centre-stage. However their appeal to young minds is strong and growing with the advent of new space missions to discover alien life, dark matter, the origin of the universe, etc. The possibilities for school-based experiments in this area may seem limited. A little imagination and stretching of the school experiment concept reveals what can be done to engage secondary students in a very active way.

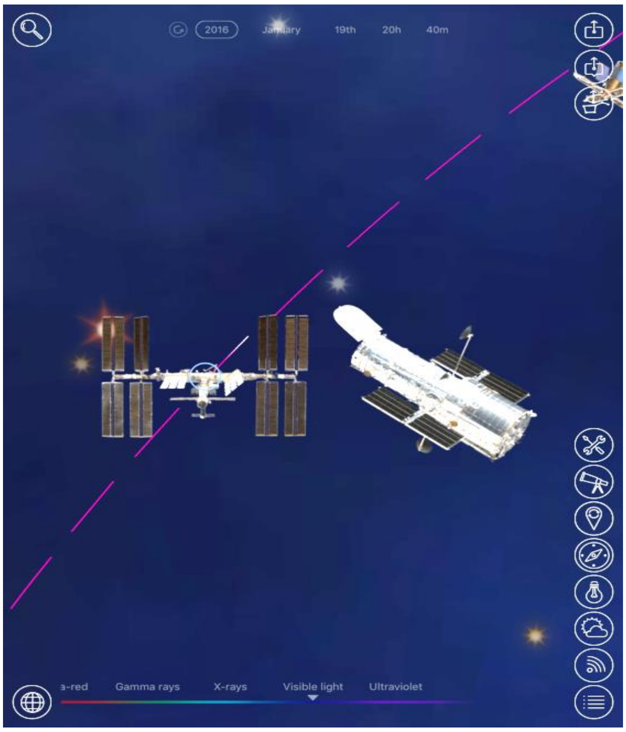

Fig.1. Screenshot of Night Sky Lite mobile application showing the real-time path of the International Space Station, ISS (dashed line) and the position of the Hubble Space Telescope

** Editorial note: the author was invited to give a keynote lecture at TPI-15, but unfortunately was unable to attend. We are happy to publish the written version of his talk here.*

APPS FOR ASTRONOMY

Night-school would have been a good option for the astronomy teacher. The unfortunate obstacle to astronomical fieldwork for day-school students – where lessons are given during daylight hours – is easily surmounted with the student's smartphone: simply download one of the many gps-enabled star-watcher apps and you have in your hand a tool to see the stars behind the glare of blue sky or cover of grey cloud. Orientating a phone loaded with free or a low-cost app such as "night sky" [1] allows the student to view planets, stars, galaxies and satellites as if in their actual positions. Immediate access to information about a plethora of astronomical objects is granted. This accessible tool gives an excellent starting place for the various topics studied in secondary school astronomy. For example, the topic of orbital path may be approached via discussion then location of the International Space Station. The app reveals real-time position and orbital path of the ISS in the sky. Fig.1. shows a screenshot of this app, tracking ISS with Hubble very close by. For older secondary students, orbital speeds may be estimated, then orbital altitudes.

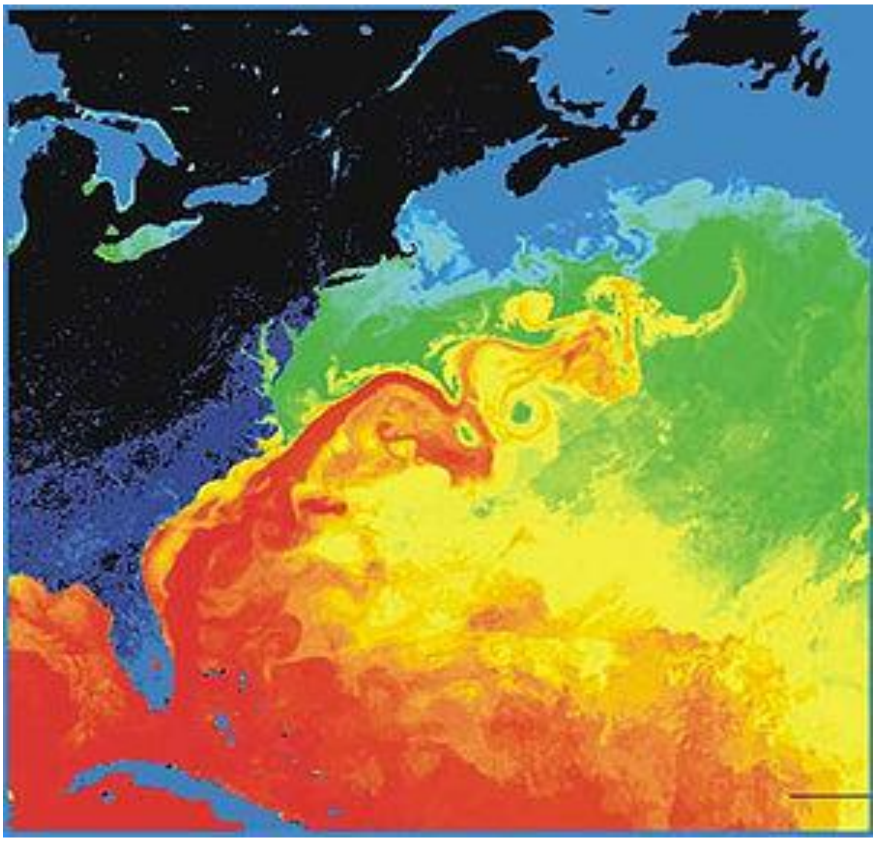

Fig.2. Composite image of the sea surface temperature of the Atlantic Ocean (the continent of North America and Cuba in dark colors) which can be analysed by ESA softwares

USING SATELLITE DATA

For students with a stronger interest in the human condition, we can look the other way, down from space to observe Earth. The European Space Agency (ESA) allows access to data from its fleet of earth-monitoring satellites. Students may download a software tool, "Leoworks" [2], in order to analyse the data. The ESA education department produces tutorials [3] to guide students through image analysis in a range of contexts. As an example we look at a set of images of the Atlantic Ocean taken in infra-red over a six month period. Fig.2. shows one such composite image for one month in 2012. Wavelength is related to sea surface temperature and colour-coded in the images, approximate range blue 275K to red 300K. Thus ocean currents and seasonal changes are made visible.

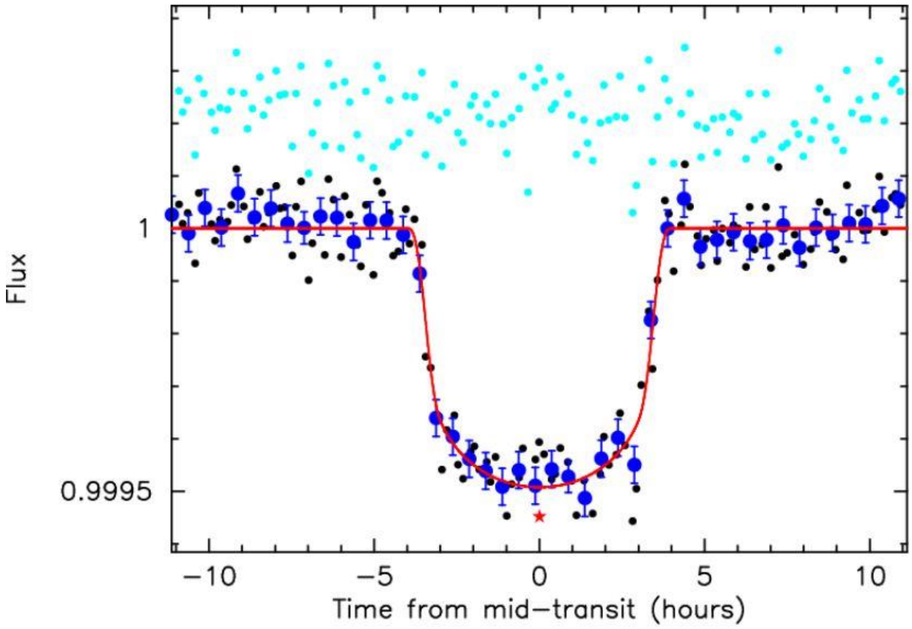

Fig.3. A centered transit light curve of Kepler-22b (dark blue dots), the first known exoplanet in the habitable zone of a Sun-like star. Light blue dots indicate the difference between the measured data and the fitted light curve (red line) on arnitrary scale.

PLANET-HUNTING

With the launch of the Kepler planet-hunting space telescope in 2009, the science fiction of other worlds has been brought crashing into science reality. The hard data beamed down from Kepler makes splendid material for the imaginative astronomy student. NASA provides tutorials [4] to get students started on analysing the light curves of stars as their planets transit, the tiny dips in brightness of the star being the starting point for a detective-trail to discover the nature of these other worlds. Although not yet appearing in many syllabuses, exoplanet work allows a new perspective on standard schoolwork about our own solar system: discussion of the "Goldilocks Zone" and a link with life sciences through criteria for habitable planets. Fig.3. shows a processed light curve for the famous Kepler 22b, the first known exoplanet in the Goldilocks Zone of a Sun-like star. Students may use measurements from such light-curves in detective work to deduce more information about the planet.

USING FILM CLIPS

Space has always been a popular theme for Hollywood. With the border between science fact and science fiction always on the move and the familiarity of students with this medium from the ease of online access, there are increasing possibilities to make good use of these films in science lessons. Whether it is true-to-life drama as in the rescue of the Apollo 13 mission (Fig.4.) or more speculative cinematography such as the visual representations of black holes as in "Interstellar" (Fig.5.), by careful selection of appropriate clips we can tease out physical principles. There are many good examples, but 2 suffice here.

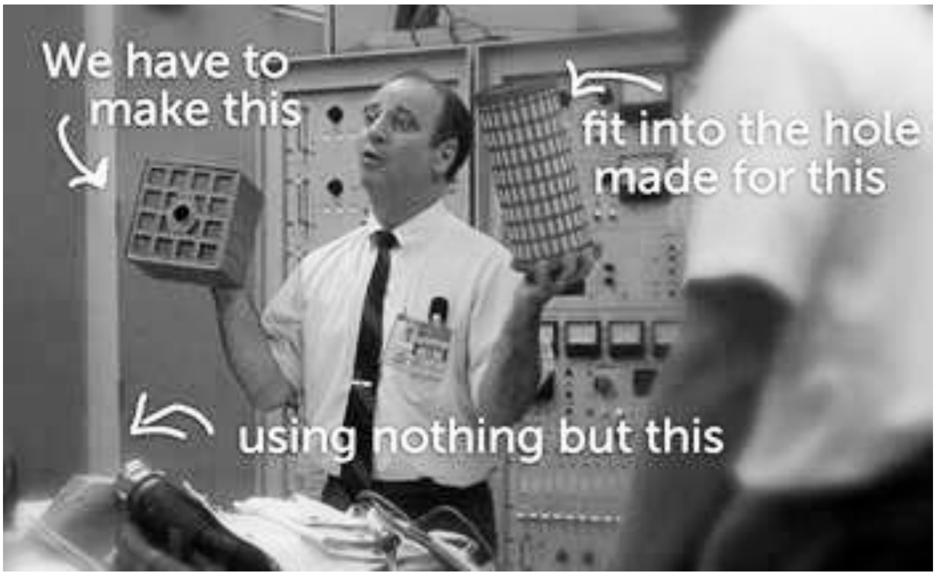

Fig.4. Screenshot from the movie "Apollo-13" [Universal Studios]

First the 1995 Universal Studios film “Apollo 13” [5] for which a series of short clips is readily available online. The clips suffice both to indicate the plot and to give a sense of the growing tension of the rescue mission. A “problem-solving” lesson may be constructed whereby class viewing of the clips is interspersed with sessions where short problems related to each clip are posed for the class groups. The problems cover a range of topics such as simple kinematics, fuel consumption and current electricity via battery life. Fig.4. illustrates such a possibility with the clip in which Ground Control solve the problem of fixing the CO_2 scrubbers with limited materials.

Fig.5. Screenshot from the movie "Interstellar" [Warner Bros]

A second example is furnished by the 2014 Warner Brother’s film “Interstellar” [6], a film in which the astrophysicist Kip Thorne [7] was intensively involved in order to sustain the scientific integrity of the more speculative aspects of black-holes, worm-holes and time-travel! Again, via a series of short clips, a lesson may be constructed that satisfies young people’s thirst for discussion of matters at the very borders of scientific enquiry whilst still fulfilling some curricular requirements. Younger students may be posed simple physics calculations (density, gravitational field strength and weight, speed, distance, time) and older students may consider the problems thrown up by planets orbiting black holes. In Fig.5. the interstellar crew have arrived on the watery “Miller’s Planet”, in orbit around a black hole. Time dilation is huge, local gravity is 130% of Earth’s.

CONCLUSIONS

These four examples of how relatively new media may be used in the secondary school Physics classroom are the tip of the iceberg of possibilities for engaging young minds with this area of the curriculum. Although some imagination and time is required for teachers to design the lessons and starting points for projects, help is at hand from space agencies and app developers. The benefits for student motivation and enthusiasm far outweigh the investments.

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COLLABORATIVE, ICTS SUPPORTED LEARNING SOLUTIONS FOR SCIENCE EDUCATION BASED ON THE SSIBL FRAMEWORK

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ABSTRACT

PARRISE ("Promoting Attainment of Responsible Research and Innovation in Science Education", 2014-17) is a project of the 7th Framework of the European Union, involving a transnational community of science teachers, trainers, communicators, and curriculum experts from 18 institutions in 11 countries. Its major objective is to engage young people in learning science through experiencing its societal impact. The paper introduces the educational framework for socio-scientific inquiry-based learning (SSIBL) and shows results of its implementation in a teacher professional development course series at ELTE University, Faculty of Science, to enhance the pedagogical repertoire and increase affective components of science literacy of teachers.

INTRODUCTION

In Hungary, student performance in national as well as international science surveys keeps declining while best students still excel at International Student Olympics and other competitions. Educational efforts seem mainly to target high performers and transmits knowledge and skills necessary to embark on a scientific or technological career. We hope to modify this situation through developing an awareness in science teachers towards socially relevant issues – an aspect that is emphasized as increasingly important all over Europe, according to a recent study by the European Commission [1]. When engaging in socially relevant topics, a wider range of students may be motivated to learn science and eventually become a better informed and more engaged citizen.

We joined the EU-supported *Promoting Attainment of Responsible Research and Innovation in Science Education (PARRISE)* project to take part in the development and adaptation of its new framework in collaborative, ICTs-supported learning environments for use for establishing new in-service training programs for Physics teachers. Our major objective is to provide alternatives for traditionally hierarchical, driven by methods transmission in-service training and create a network of knowledge-builders –a community of teachers supported by resources shared through digital technology (the Moodle e-learning environment and social computing tools). A training course for experienced and innovative teacher communities like those applying for admission to one of Hungary’s leading research universities, seem to the best environment for presenting and adapting new models through networked learning methods [2]. In this paper, we introduce the SSIBL concept and show how it is being used for the professional development of Hungarian teachers.

THE SSIBL FRAMEWORK: A NEW MODEL FOR INTRODUCING RESPONSIBLE RESEARCH SCIENCE EDUCATION

The SSIBL Framework is being developed by the PARRISE project, a European community of science teachers, teacher trainers and educational researchers whose actitivies centre on integrating current issues of science and society at school. Through experiencing the societal impact of research and innovation, this approach intends to increase the agency and motivation of young people for pursuing studies in science. By becoming more scientifically literate, young citizens are better equipped to participate in the process of science innovation. PARRISE also intends to improve pre- and in-service science teacher education through sharing best practices of professional development for primary and secondary teachers in Europe.

The project objectives are as follows (cf. [3] for details and publications):

1. Provide an overall educational framework for socio-scientific inquiry-based learning (SSIBL) in formal and informal learning environments;
2. Identify examples of best practice;
3. Build transnational communities consisting of science teachers, science teacher educators, science communicators, and curriculum and citizenship education experts to implement good practices of SSIBL;
4. Develop the SSIBL competencies among European primary and secondary science teachers and teacher educators;
5. Disseminate resources and best practice through PARRISE website, digital and print-based publications online and face to face courses authored by national and international networks;
6. Evaluate the educators' success using the improved SSIBL materials with pre-service and in-service teachers.

The project team collects and shares existing best practices in European science education and develops learning tools, materials and professional development courses for based on the SSIBL approach. *Socio-Scientific Inquiry-Based Learning* (SSIBL) is meant to address the need for a heightened awareness of the role of research in contemporary society through expanding teachers' perceptions about the aims and objectives of science education. The model is based on the concept of Responsible Research and Innovation (RRI).

> *"At the moment, Europe faces a shortfall in science-knowledgeable people at all levels of society and the economy. Over the last decades, there has been an increase in the numbers of students leaving formal education with science qualifications. But, there has not been a parallel rise in the numbers interested in pursuing science related careers nor have we witnessed enhanced science-based innovation or any increase in entrepreneurship. Science education research, innovation and practices must become more responsive to the needs and ambitions of society and reflect its values. They should reflect the science that citizens and society need and support people of all ages and talents in developing positive attitudes to science. We must find better ways to nurture the curiosity and cognitive resources of children. We need to enhance the educational process to better equip future researchers and other actors with the necessary knowledge, motivation and sense of societal responsibility to participate actively in the innovation process" [4].*

The SSIBL framework [5], [6] connects RRI with three pedagogical concepts. *Inquiry-based Science Education* (IBSE): this model has always been at the core of Hungarian Physics education, and is being gradually adapted by other science disciplines as well. It focuses on empowering students to act as researchers and them not only facts also problems and solution scenarios to experiment with. Case studies, field-work, investigations in the school laboratory or even complex or research projects can be involved in this educational approach. Teachers who employ it believe that ideas are fully understood only if they are constructed by students through reflections on their own experiences. For STEM (Science, Technology, Engineering and Mathematics), this approach is especially important, but may be successfully used in the arts and humanities as well (EC-FP7 projects promoting an IBSE approach are, for example, PROFILES, SAILS, Pathways, PRIMAS or Fibonacci) [7]. This model has proven useful also in teacher professional development [8].

Socio-scientific Issues (SSI) are open-ended science problems which may have multiple solutions. Most of them involve controversial social issues as well, which are closely connected to research and innovation in science. SSI may be successfully utilised in science education to enhance the ability to apply both scientific and moral argumentation and develop solutions in relation to real-world situations like climate change, genetic engineering, advertisements for increased consumption of unhealthy food, animal testing for cosmetic purposes, or the use of nuclear power as cheap and clean energy resource. SSI is highly efficient in promoting scientific literacy and increasing students' understanding of science in various contexts. Involvement with controversial scientific issues also enhances argumentation skills and, through developing empathy, contributes to the acquisition of moral reasoning.

Citizenship Education (CE): “can be defined as educating children, from early childhood, to become clear-thinking and enlightened citizens who participate in decisions concerning society. ‘Society’ is here understood in the special sense of a nation with a circumscribed territory which is recognized as a state” [9]. It involves an awareness of the rules of law and other regulations that concern social and human relationships. CE also provides an orientation for the individual on ethics the rights inherent in the human condition (human rights); and those that are related to being the citizen of his country, civil and political rights recognized by the national constitution of the country concerned. Recent research on citizenship education in science shows that focusing on civil rights and responsibilities can be efficiently integrated with teaching about responsible research and innovation [1]. The interrelations of these four pillars of the model are represented in Fig.1.

Fig.1. The Socio-Scientific Inquiry-Based Learning (SSIBL). Source: [6]

METHODOLOGY

In our first teacher professional development (TPD) course for teachers of Physics, based on the SSIBL framework and delivered in the second half of the academic year 2014-15, we organised a networked system of learners who developed active, collaborative agency around shared knowledge objects, according to the trialogical model of learning [10]. Teachers as knowledge builders worked and learnt together in a mentored innovation setting [11]. This setting is meant to introduce teachers new methods through investigating their pedagogical needs and offering new strategies that suit them best. The learning triangle involves the teacher as learner and peer tutor at the same time, a mentor who also acts as role model for teaching and research, and a knowledge object: in our case, a new learning unit to be developed (Fig.2.).

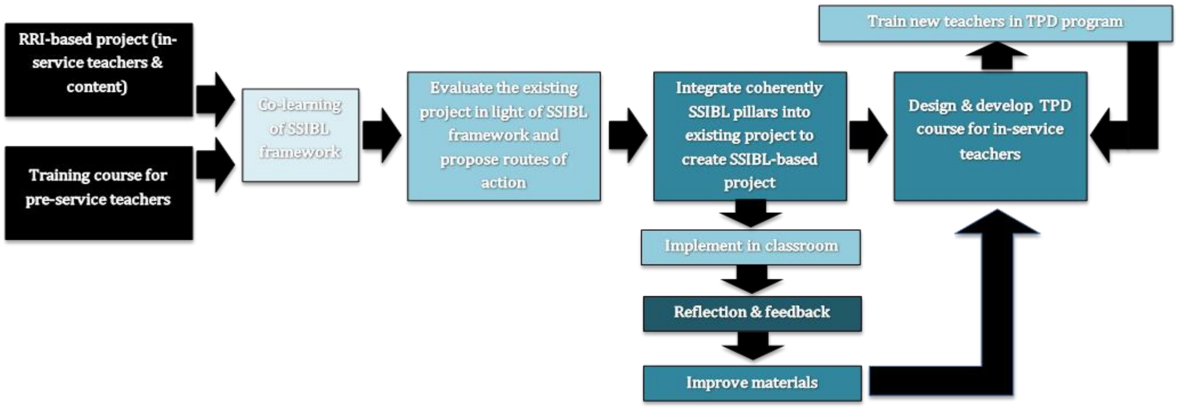

Fig.2. Model for the Hungarian in-service teacher training program based on the SSIBL framework

One of the goals set for the teacher network was to investigate a socially sensitive scientific domain, namely, the use of nuclear energy. We used the Moodle e-learning environment for sharing good practice and discuss issues of adaptation, and also employ social computing (Web 2.0) tools like science blogs and interactive science portals – a format especially important to meet changes of science media consumption [12].

Teachers were expected to introduce the SSIBL framework in their teaching as they felt most appropriate (in the form of an interdisciplinary lesson, a project week, an informal learning opportunity in a science centre or museum, or in a lesson sequence addressing socially sensitive research issues). TPD participants delivered a pedagogical essay and digital teaching materials on strategies of teaching about one of the four main subject areas of the course: modern physics, microphysics, astronomy, and chaotic dynamics and manifest how they adapted the educational framework explained in this paper. Community driven inquiry learning based on progressive inquiry and collaboration was especially suitable for involving students in disputed, social issues related to science [13]. The four pillars of SSIBL were employed in structuring course content:

1. RRI: traditionally, scientific discoveries are described as a final product of research. In this course, they were presented as *an interrelated complex of research endeavours and relevant social processes*. First, the conception of the research idea and (potential) social needs manifest in it was presented, then phases of the research where social issues were at stake were highlighted. Finally, a discussion of related innovations that raised social issues.

2. IBSE: *presentations were followed by experimentation*, where teachers acquired new scientific investigation skills. For example, they learnt how to apply information and communication technology (ICTs) tools for modelling processes and exploration of data. Teachers were also informed about still unresolved issues and encouraged to enhance student skills to develop different explanations.

3. SSI: most of the topics included in this course have *high social relevance for Hungary* (e.g. the generation and use of nuclear energy, “Big Bang” and Creation “theories”, the butterfly effect and other naïve beliefs and scientific explanations, etc.). Media

coverage of these issues were discussed and the moral implications of science communication – a field bordering on science education – was revealed.

4. CE: teachers were expected to act like responsible citizens (and trainers of such) and identify connections among current research in the field of Physics, critically reflect on curricula and propose means for future improvement, involving the inclusion of the results of New Physics.

CONCLUSIONS

The first iteration of the course, with nuclear energy and related social issues in focus, suggests improved social skills and heightened interest in the public understanding of science and research based policy making – both necessary for developing responsible researchers and citizens as well. We hope to have *introduced social and ethical concepts* that promote teachers' reconceptualization of their teaching content and do beyond teaching, towards the education of morally responsible, ethics-driven citizens [14]. Teachers have retooled their teaching processes through the *employment of ICTs solutions* as simulations, measuring tools or communication devices that facilitated the creation of an interactive science education environment. ICTs solutions should not replace real life experiments, but are inevitable for widening access and also for introducing experiments that were impossible to deliver otherwise in a classroom setting.

A second iteration currently undertaken centres around climate change – another crucial issue for Hungary where agriculture is a major factor in national economy. In this iteration, we intend to *increase the collaborative aspects* of our TPD. Collaborative knowledge building in teacher education is planned to relate to learning that occurs partially in an informal setting, the Moodle virtual learning environment that supports situated cognition and situated learning in knowledge building communities. In its ideal form, such a collaboration involves the mutual engagement of learners in a coordinated effort to solve a problem together or to acquire new knowledge together [15]. We intend to use cooperative learning methods based on cognitive apprenticeship that result in knowledge-building communities that offer peer tutoring and support [11]. In these collaborative learning models, mature communities of practitioners participate in inquiries at the frontiers of knowledge. Their activities with their mentors during the TPD process will be characterised as a transformative communication for learning.

Through collaborative methods [16], we hope to embed social issues relating to science in Physics education while retaining its major merit: its hands-on, experiment-based character. We also hope to empower Physics teachers to realise the goals of *The Framework for Science Education for Responsible Citizenship*. Its 5th objective: "Greater attention should be given to promoting Responsible Research and Innovation (RRI) and enhancing public understanding of scientific findings including the capabilities to discuss their benefits and consequences", Its 6th objective: "Emphasis should be placed on connecting innovation and science education strategies, at local, regional, national, European and international levels, taking into account societal needs and global developments" [1]. Both are in line with the SSIBL Framework and the methodological repertoire currently under development by an international team with the membership of the authors of this paper.

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HANDICRAFT AND AESTHETIC EXPERIENCE IN TEACHING CHAOS PHYSICS

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ABSTRACT

Our aim is to raise awareness of the importance of getting acquainted with chaos physics in the frame of teaching modern physics. We would like to present a good practice of a series of lessons with a focus on handicraft activities. Apart from raising interest, experiencing the joy of creating something, the activities may help students understand and deepen their knowledge of chaos physics.

INTRODUCTION

We examined the opportunities of getting acquainted with chaos physics within the framework of secondary school physics education, as I presented in a Hungarian language article [1]. We researched the methodology of inserting chaos physics within the secondary school curriculum, presented chaos experiments, introduced IT opportunities and also reviewed the use of art as a ’motivational tool’.

In this article we present how art workshops inserted in a series of chaos physics lessons are capable of raising interest in physics and the chaotic phenomena within thereof, and shall provide opportunity to explore the features of chaos. Our aim is to raise awareness of the importance of getting students acquainted with chaos physics within the framework of modern physics education, we shall provide ideas thereto and present some good practices.

We encounter chaotic phenomena not only in our everyday life [2], but also in nature: at the change of ocean plankton colonies in space and time (see e.g. [3]); or fluid layers mixing in turbulent sea, or in meteorology [4] the spread of clouds of pollutants. We can also take the shooting stars across the sky at summer nights as examples, which trace out the final phase of the chaotic motion of small asteroids. Another example can be the oscillation of the heart and brain activity, or the oscillating chemical reactions.

As we notice, chaotic motion is not exceptional but typical. It is the complex behaviour of simple systems [5]. The main characteristics of deterministic chaos are: the equations describing the motion are known; these equations are nonlinear; the motion is irregular and unpredictable; there is order in the phase space: the fractal [6] structure. As these phenomena are so typical for physics and everyday life, chaos physics should belong to the physics curriculum.

THE PLACE OF CHAOS PHYSICS IN SECONDARY SCHOOL PHYSICS EDUCATION

In a former research we investigated how the possibility of teaching chaos physics may be implemented in secondary school physics education [1]. We examined two education systems: a Romanian model and a German model. Teaching the elements of chaos physics is part of Modern Physics in the examined Romanian model, whereas similar elements are integrated in the relevant chapters in the other model.

Chaos physics can be defined as modern physics in a non-conventional sense. Currently, chaos physics is not part of the official documents of the Hungarian secondary education. In a series of lessons, we examined the possibility of implementating chaos physics and our recommendation was given in a syllabus prepared on the basis of the national curriculum (NAT): we concluded that it should be connected to topics related to environmental physics. We may encounter several environment-related topics within the syllabus, which is rich in terms of different phenomena; however, the depth of understanding is rather low. We think that chaos physics should have an important role in the preparation and academic founding of these topics.

I have developed a teaching unit that I have implemented in different classrooms. This unit includes complementary contents to the already existing curriculum. As a first step the teacher familiarizes students with chaos theory and its characteristics throughout simple mechanical examples (e.g. magnetic pendulum, double pendulum, double slope [6]): the unpredictability, the order appearing in phase space, the fractal structures. As a second step, students are familiarized with mathematical fractals. As a next step the teacher demonstrates that fractal structures become visible during chaotic mixing. Students can observe fractal patterns during mixing (mixing cream in coffee, syrup in water, ink in water, or during mixing different paints). The main hands-on activity of this teaching unit is marbling. During handicraft activities students experience the process how patterns develop. After the hands-on activities we return to the topic of environmental flows. Students will be able to recognize similar patterns when encountering environmental contamination.

The method of inquiry-based learning is applied. Inquiry-based learning includes problem-based learning. Most of the PBL-defining characteristics listed by Schmidt [7] appear during the teaching process I implemented: problems are used as an activator for learning; students co-operate in groups for part of the time; learning takes place under the supervision and guidance of the tutor; this curriculum of chaos physics consists of a limited number of lessons. In certain situations learning is student-initiated, and we often provide time for self-study.

It is important to know what competencies the students develop while getting acquainted with chaos physics. Cooperation among the students is improved with team work. The group activity provides a good platform for collaboration and the development of friendships among students in addition it facilitates making closer contacts between the students and the tutor [7]. The interdisciplinary concept of the students is largely strengthened during these lessons. On the one hand, the aesthetic experience is suitable to raise interest and to motivate, whereas the classroom activity itself develops visual and aesthetic viewpoint. The students have the opportunity to observe, compare and interpret the phenomenon. Their competency of thinking in pictures is developed; they will be able to recognise similar patterns in different situations. It is very important to note that these are not fictional and virtual pictures, but pictures occurring in nature.

WHY SHOULD WE USE HANDICRAFT TO FAMILIARIZE STUDENTS WITH CHAOS PHYSICS?

In the above-mentioned series of lessons handicraft activities play an important role. The reason for this is the peculiarity of chaotic mixing. Fractal structures always appear in chaotic processes, but regularly in an abstract space, in the phase space [5], therefore they do not become visible under direct observation. Chaotic mixing, for example the spread of contamination in a drift, or the cream poured in the coffee, the mixing of paints, is an exception. In these cases fractal structures become visible also in real space. This is the reason why we have chosen to utilize it in teaching chaos physics with the aid of handicraft. The photo in Fig.1. shows an example of chaotic mixing pattern: oil on the surface of water.

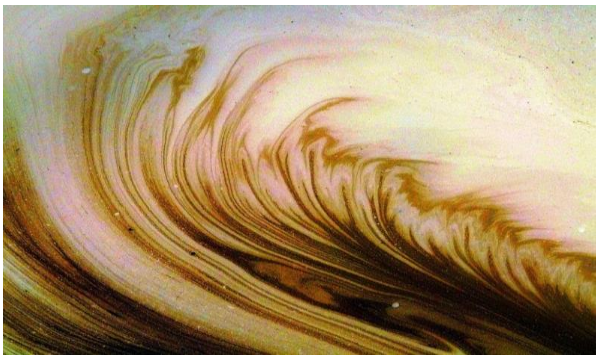

Fig.1. Oil on the surface of water (Photo: Traian Antonescu)

APPLIED TECHNIQUES (BASED ON CHAOTIC MIXING)

The following handicraft activities have been involved in teaching: painting paper, candles and eggs with marbling technique. The most important technique is marbling [8], which is chaotic mixing in two dimensions.

The steps of marbling technique are the following: 1. Small amounts of two or three different marbling paints are poured on the surface of water. 2. Marbling paint is mixed (Fig.2.a)) presents the mixing of paints). 3. A sheet of paper is placed on the surface. 4. The sheet is flattened against the surface using quick but definite movements so that it can get in full contact with the surface and the paint as Fig.2.b) indicates. 5. The sheet is grabbed and lifted up carefully as it is shown in Fig.2.c). 6. As a result, marvelous fractal structure becomes visible with nice Cantor-filaments.

Fig.2. a) Mixed paints on the surface of water, b) Sheet flattened against the surface of water, c) The painted sheet lifted, fractal filaments become visible on the paper

HOW HANDICRAFT ACTIVITIES HELP STUDENTS UNDERSTAND THE ESSENCE OF CHAOS

Chaotic mixing is the most essential, the most familiar and the most spectacular phenomenon of chaos. In one of the introductory classes we examined the spread of a paint drop or a drop of contaminant in a tank with two drain holes which is also an illustration of chaotic drifting. It is surprising that the drop changes its original shape in a very short time in a way that a well-defined fractal structure becomes visible meanwhile each particle describes its own chaotic path [6]. This structure is very similar to the patterns made by the students during the handicraft activities. Therefore, the aesthetic experience during handicraft activities is suitable to raise interest and to motivate students.

During painting with marbling technique students have the opportunity to gain experience with chaotic mixing phenomena. It is a guided experience: they observe with attention for the first time how fractal structure evolves during chaotic mixing. In Fig.3.a) we can see paints on the surface of water, which is actually the result of chaotic mixing, in Fig.3.b) we can see a part of a fractal filament patterned sheet made by the students. This is the imprint of chaotic mixing, which makes students understand this aspect of chaos physics.

Fig.3.a) Paint on the surface of water: chaotic mixing, b) Fractal filament patterned sheet: imprint of chaotic mixing obtained by the students with marbling

Structures similar to the fractal structures that become visible during the marbling activity appear in environmental flows, for example in the case of spread of contaminants. Students have the possibility to compare the pattern of their pieces of arts and the pattern of oil contamination on the surface of water (Fig.4.a)) or the pattern of foam pollutants before the dam as we see in Fig.4.b).

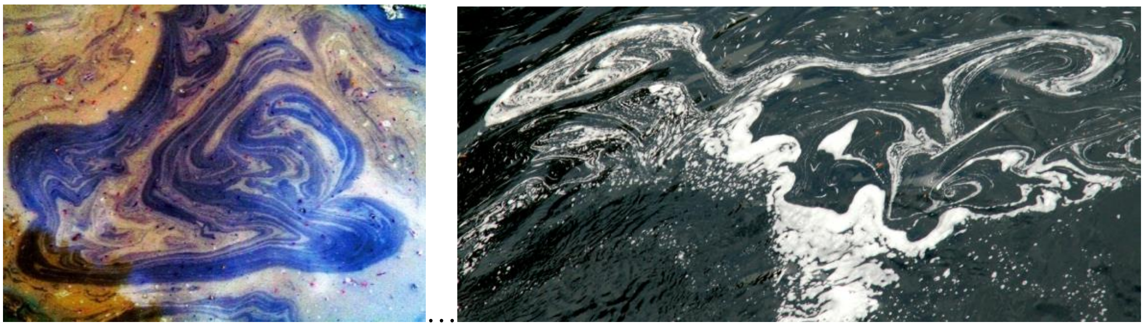

Fig.4.a) Oil contamination on a puddle (photo by Antonescu Traian),
b) Foam pollutants before a dam (photo by György Károlyi)

We aim to enhance students' competence of thinking in pictures: they will be able to recognize similar patterns in different phenomena. It is very important to note that these are not pictures of a virtual world, but patterns occuring in the natural environment.

The interesting experience related to the phenomenon will motivate students to get more deeply involved in the subject: if the experience is interesting, it will raise the curiosity of students to develop a computer program to model the phenomenon. This experience might raise motivation in students to gain the knowledge required for a deeper understanding of the phenomenon.

PAINTING EGGS, CANDLES AND PAPER WITH MARBLING TECHNIQUE

Other handicraft activities related to chaotic processes are the painting of eggs during Easter and the painting of candles during Christmas time. The steps of painting eggs are the following: 1. A stick is fixed inside a white egg so that it stays stable (blown eggs, or white plastic eggs are used); 2. The egg is fully immersed under the water. 3. Small amounts of paint (two or three different colors) are poured on the surface of water then mixed in order to have a beautiful pattern with fractal filaments. 4. The egg is taken out immediately but very slowly so that the paint is evenly distributed on its surface. 5. Care should be taken while drying the eggs (as you can see in Fig.5.a). As a result, marvelous fractal structures become visible with nice filaments as can be seen in Fig.5.b).

Fig.5.a) Drying the eggs, b) Fractal-patterned Easter eggs made by students

Before Christmas we paint candles with Cantor-filaments. The steps of painting candles with marbling technique are similar to that of painting eggs (Fig.6.).

Fig.6. Candles with fractal filaments painted before Christmas

CONCLUSIONS

The summary of the teaching unit described above that I have implemented and I find worth sharing is the following: First the teacher talks to students about chaos theory, the order appearing in phase space, the fractal structures. Then, students are familiarized with mathematical fractals. As a next step the teacher raises students' awareness that fractal structures become visible during chaotic mixing. Students have the chance to observe fractal patterns during mixing. During appealing handicraft activities students experience the process how the patterns develop and connect handicraft with chaotic phenomena.

The benefits of the teaching method can be summarized as follows:

Firstly, handicraft activities are suitable tools for raising students' interest in physics, more specifically in chaotic phenomena. Marbling gives opportunity to get to know the characteristics of chaos.

The fact that the interest of students has been successfully raised is proven by the number of students choosing chaos physics for their school project after participating in my chaos physics lessons, even students who are not considering to continue their studies in physics. Another indication is that several students have chosen fractal geometry or chaos physics as the topic of their optional presentation at physics class.

Apart from raising interest, hands-on activities are motivational tools for students who desire to obtain deeper knowledge of the chaotic phenomena, who would like to be able to mathematically describe the system or write a computer program for the simulation of the phenomenon.

Secondly, as we have already mentioned above, the aesthetic experience during handicraft activities is suitable for raising interest and motivating students. At the same time the handicraft activity in class, creation itself develops the visual and aesthetical view of students. Creating works of art, the process of mixing and experiencing the development of the pattern help to deepen students' understanding, and develop among others the competence of thinking in pictures. Aesthetic experience in class increases motivation in everyday school life.

Thirdly, we experienced that the students' interdisciplinary concept is largely strengthened during these lessons.

Finally, an important benefit related to the IBL method is the group collaboration where a platform is created for the development of friendship among students and the teamwork facilitates close contacts between students and tutors [7].

ACKNOWLEDGMENTS

I would like to express my gratitude to my professors Tamás Tél and Péter Tasnádi and to Éva Szabolcs for their support, patience and motivation.

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LEARNING KINEMATICS THROUGH ANALYSING PHYSICS IN MOVIES

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ABSTRACT

In order to increase students' motivation of learning kinematics at senior pre-university education in the Netherlands, we developed and tested a series of five lessons in which movie scenes were used. Students had to analyse whether a spectacular stunt from a movie scene could be performed in reality. Gradually students developed conceptual and procedural knowledge and learned how to establish the physical accuracy of these stunts. However, not all conceptual knowledge was firmly rooted, and cohesion between different concepts was still missing. Therefore we advise to incorporate the analysis of physics in movies in regular lessons to increase motivation and learning outcomes.

INTRODUCTION

At the 'International Conference on Teaching Physics Innovatively 2015' (TPI-15) it became clear that Hungary has a decreasing amount of students interested in choosing science, or more specifically physics, as major subject. Due to a limited budget, teachers as well as researchers have to be innovative to reach a large audience. Next to that, popularization of science subjects has to go hand in hand with an educative component: Education should be fun but instructive as well. Dutch physics teachers face similar problems as students do not relate the different subjects covered in the physics course with their everyday life. They question why it is important to learn e.g. mechanics. This study investigates the benefits of analysing movie scenes in physics class where we try to link the three components mentioned: increase students motivation by introducing a practical and recognizable problem with an educative component.

Originating from lessons in which I used movies, cartoons and bloopers, a series of five lessons was developed in which students inquire the accuracy of movie stunts: Are the stunts potentially real? The initial idea was to let students, working in small groups, investigate the physics in movie scenes. Although the teacher should not intervene, some help could be provided using questions in worksheets. It was thought that intrinsic motivation, driven by students' curiosity, should be enough to let students develop or gain the necessary knowledge to find a solution to the problem and by doing so learn kinematics. Accordingly, the research question that arose was: *To what extent are students able to develop kinematic concepts based on the analysis of movie scenes?* While motivation is a key factor for success in this approach, known as a problem-based learning approach, the second research question that arose was: *Which components of the chosen approach are appreciated by the students?*

As this is a first exploration in a cyclic process (design research, [1]), a large quantitative study is unsuitable. Therefore we chose a small qualitative study in which small groups of students were intensively monitored. The outcomes of this study reveal whether it makes sense to further develop this teaching strategy.

THEORY

At the heart of science lie the inquiries in which existing knowledge is used and new knowledge is acquired. Inquiries in which students work in small groups on problems where they still lack the prior knowledge to solve the problem directly is known as a problem based learning (PBL) approach [2], [3]. By investigating and discussing the various problems, the necessary knowledge to answer the questions is developed along the way [4]. This creates a shift in responsibility for learning: The teacher does not tell students the relevant information but the students investigate themselves what is necessary to know to solve the problem. This approach is often used at university level with medical students. However, not much is known about the potential success of this approach at secondary school level. Still this approach can be useful as many benefits are known to exist, among them [2],[5],[6]: (1) PBL aligns with how people learn science; (2) PBL stimulates active engagement and responsibility for one's own learning; (3) PBL fosters the acquisition of lifelong learning skills; (4) PBL increases problem solving abilities; (5) PBL motivates students to learn; (6) PBL improves conceptual learning; (7) PBL positively changes students' attitude and interest in physics.

However, opponents of this approach suggest that this teaching method leads to incomplete and disorganized knowledge. Students can acquire misconceptions [7]. It is questioned whether there is any room left for students to inquire themselves and students often lack motivation to continue an inquiry for longer times. So the question is whether this approach is suitable for less independent secondary school students.

One way to motivate students is to use movies, as these tend to appeal to a large audience. This certainly follows from the fact that students spend more and more time in front of the TV [8]. We could use this interest to teach physics as many physical phenomena can be seen in movies and even physical phenomena which cannot be seen in everyday life are produced within movies [9]. Many examples of using movie scenes have been mentioned in e.g. '*The Physics Teacher*' [10], [11]. Questioning whether the shown event is potentially real could arouse students' curiosity. This question is answered in many different ways by several TV programs such as '*The big bang theory*' and '*MythBusters*' to involve the viewers [12], [13]. Whether it is possible to use the same approach to bind students to the various science subjects for a longer time and instantaneously teach them to solve problems, remains a question for now.

Next to the potentially appealing way physics is presented, the visualisation of physical phenomena can also enhance student learning as they are able to see the phenomena over and over again, analysing them in detail. In this way, the mathematical equations for e.g. parabolic orbits, difficult for students, could come to life and could gain meaning and relevance to students. This could support them in a further analysis of the physics involved.

METHOD

In this design research we investigate possible affectional effects and the development of procedural and conceptual knowledge through analysing kinematic phenomena in movie stunts using a PBL approach. In order to do so, we developed a series of five lessons using recommendations on conceptual development in physics teaching and strategies for effective use of a PBL approach.

This series of lessons was tested in a single 5 VWO class (senior pre-university education) of 18 students. These students (aged 16/17) were divided into groups of three to four persons with the same academical abilities. Three groups were video recorded, the other two groups were audio recorded. After each lesson transcripts were made and subsequently students' activities, including chosen solution strategies and given answers, were analysed. In addition, we studied the development of kinematical concepts during the small group discourses. In order to do so, first the different kinematical terms were highlighted and subsequently we investigated how these terms came forward: e.g. by discussing or questioning and whether these terms were given the right interpretation of physical meaning.

DESIGN

A literature study on the use of an effective PBL approach in class yielded many recommendations. A PBL problem should at least [5,6,14]: (1) not have a single solution or solution strategy; (2) be authentic, concrete and have value; (3) match the students' level of prior knowledge; (4) engage students in discussions (5) lead to the identification of learning issues; (6) stimulate self-directed learning and (7) be interesting to students. As we use a PBL approach in a physics class, recommendations on effective physics teaching should be used in the design as well. Knight [15] summarizes that physics lessons are more effective when: (1) students are actively engaged; (2) lessons focus on phenomena rather than abstractions; (3) students have to explicitly deal with alternative conceptions; (4) students develop problem solving skills and strategies and (5) problems with a quantitative and qualitative character which go beyond symbol manipulation are used. The combination of these 12 recommendations has led to a series of lessons where:

1. Forrest Gump [16] is running across the countryside at a constant speed. In various instances, his speed can be determined and compared with that of an average jogger, showing that he is fairly slow. Students' prior knowledge was activated (uniform linear motion) and they gain experience in using the interactive whiteboard (IWB) in combination with movie scenes.
2. Criminal Bohdi is chased by agent Johnny [17]. With a 15-second interval they jump out of an airplane. Still Johnny overtakes the felon in mid-air by minimising his frontal area. Again, prior knowledge (free fall) was activated but their knowledge was extended by introducing friction.
3. Trinity [18] escapes from agent Smith by jumping from one building to another across a two-way street. Her trajectory is fairly well shown in slow-motion, making a proper analysis of the jump possible and therefore this lesson served as start on projectile motion, where step by step the independency of motion in horizontal and vertical direction was introduced.
4. Four boys find themselves trapped with their car at a collapsed bridge, see Fig.1. [19]. They dare to jump across as one is certain that physics tells them it is possible to do so. They get across, although the car disintegrates. All necessary variables (and more) to solve the problem are mentioned in the conversation between the boys. Therefore, this lesson served as a practice on the topic of projectile motion.

Fig.1. The car jump in Road Trip (2000)

5. Raines escapes from the police by jumping over a bunch of stationary cars using a ramp loader at 100 mph [20]. All necessary variables to analyse the jump are 'hidden' in the scenes, students had to find these variables. This lessons served as a formative assessment where students showed their gain in procedural and conceptual knowledge during the series of lessons.

Questions in the worksheet served as stepping stones. Although these questions provided some help, there was enough room to discuss and inquire the different kinematical concepts.

RESULTS

As students worked in small groups, in each lesson and with each question a same process of inquiry was observed. We call these phases of inquiry: the *orientation phase*, the *analysis phase*, and the *solution phase*. These phases are elaborated consecutively.

In the *orientation* phase students discussed what the actual problem was and how to, qualitatively, describe the event shown in the movie, i.e. they made the problem understandable for themselves. In this phase, kinematical terms automatically came forward, although these were not always given the right physical meaning, as the following excerpt from lesson 2 shows, where students S1-S3 discuss a fall with friction:

1	S1:	But it is not like he is falling slower?
2	S2:	No, he falls constantly. You have to fall constantly otherwise you would smash into the ground.
3	S1:	But that is the case. Only the parachute will save him.
4	S2:	The acceleration isn't increasing? Is it?
5	S3:	No, not increasing.
6	S1:	Why not?
7	S3:	No, the acceleration is not increasing, while…
8	S1:	S9… Is the acceleration increasing when you jump out of a plane? Or is the acceleration constant? You will fall harder, isn't it?
9	S3:	You fall constantly, right?
10	S1:	The velocity increases.
11	S9:	The velocity increases, but not the acceleration.
12	S1:	So… You don't accelerate?
13	S10:	At a certain moment you won't accelerate anymore. You just fall with 150 mph downwards.
14	S2:	So, the gravitational force is constant.
15	S9:	The acceleration is getting smaller.
16	S10:	If you did not accelerate at the start you would float in the air.

As students reached consensus about the interpretation of the different kinematical terms, they proceeded to the *analysis phase* in which they investigated the relations between the different terms. In lessons 3, e.g. they explored how Trinity's vertical displacement depends on time. Stimulated by the movie, some groups displayed the movement to each other by gesticulation, see Fig.2. The movie stunt was shown over and over again, where students discuss the different relations between variables. In some cases they used a digital ruler to determine lengths or areas. Each time when this was done, they compared their answers with their prior-knowledge: Does the measurement make sense to what we already know?

Fig.2. One student trying to relate the actual jump with the velocity of the jumper. Her hand showing the jump

In this phase, discussing and questioning each other are the main types of communication. Most struggles in understanding the physics showed up in this particular phase, as students still lacked the necessary knowledge and had only each other, a formula sheet and the movie to develop new knowledge. Especially with transferring formulas and events to graphs was difficult for them. This is not surprising as this is a well-known problem in literature [21], [22]. However, when they reached an analysis that satisfied them, they moved on to the *solution phase* in which they formulated their final answer to the problem. It is worth noting in this phase that students evaluated their answers with their common everyday knowledge and the event shown in the movie, shown e.g. with this excerpt from lesson four:

1 S3: 104 km/h! That's fast.
2 S1: But it is logical that they make so much speed.
3 S3: Okay, but on such a small road…

As a teacher, we like to have students evaluate their answers, but often they do not see their own mistakes, even when answers diverge on the order of 10^6. In these tasks, students evaluated their answers spontaneously and referred to daily observables, i.e. link the physics with well-known events.

In the final assignment, students show what they learned as demonstrated in Fig.3. (Appendix) This student clearly shows which variables are necessary to analyse the jump, calculates the airtime and the jumping distance. This distance (127 m) is clearly greater than the jumping distance as shown in the movie.

Motivational aspects

As students started with a kind of eagerness to work with the movies, they quickly lost some of their interest during the series of lessons as they felt it was rather a matter of repetition. According to them, each lesson resembled the previous one. Although students said to lose some interest, this was hardly reflected in the lessons: most of the time they were cooperatively working on the problems. In the questionnaires as well in the interviews, students mentioned that working together on a problem that had a practical relevance appealed to them, illustrated by a quote of one of the respondents: "*It is more fun because you understand what it is you are actually doing.*" Working in small groups provided direct feedback and students appreciated the possibility to discuss several problems. Similar problems embedded in a series of lessons with instructional lessons would appeal to them even more as they were uncertain whether their approach was the right one.

DISCUSSION

During the various lessons we saw the same solution process over and over again. Students did not stick with only an analytical analysis but also tried to include the movie scene itself to solve the problem, e.g. by measuring jumping distance or airtime. Although not always successful in terms of giving a scientifically satisfying answer, students developed the procedural skills to analyse a movie scene in terms of physical accuracy. This was shown particularly in the formative assessment in which students directly knew which variables had to be determined and how in order to solve the problem. Furthermore, we see that the conceptual knowledge was extended during the various discussions held. During these discussions kinematical terms come forward and gained meaning for the students. However, not all kinematical terms obtained a scientific interpretation and the relationships between the various concepts and kinematical terms was missing. Students would like to obtain a summary of all the kinematical concepts involved. However, this can also be seen as a benefit from using this approach, as students know their own knowledge deficits, they ask more profound questions during instructional lessons and they have an intrinsic motivation to pay attention as they know why the instruction should matter to them.

CONCLUSION

The developed series of lessons has proven to offer interesting practical problems for students at the age of 16/17. The problems provide a link between physics and the context in which physics is present. Integrating these ideas in different lessons would lead to enthusiastic teenagers eager to debunk Hollywood movie stunts, who instantaneously learn physics.

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APPENDIX

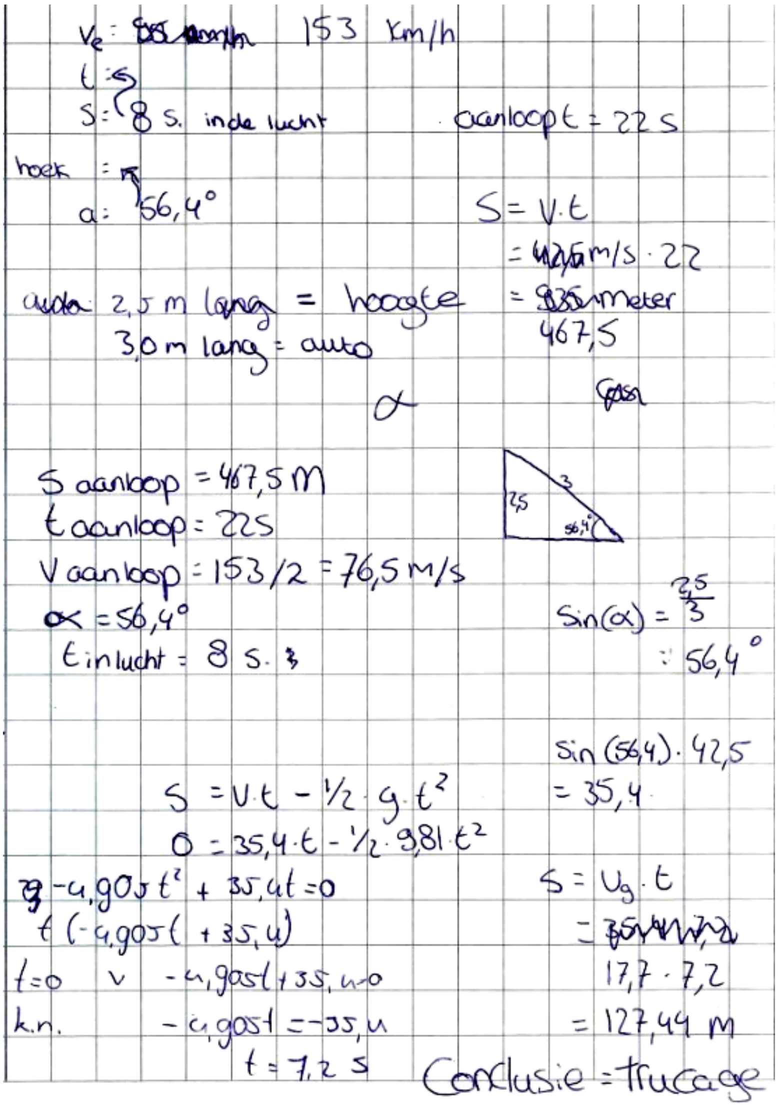

Fig.3. A student’s answer on the question whether the jump could be made

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.

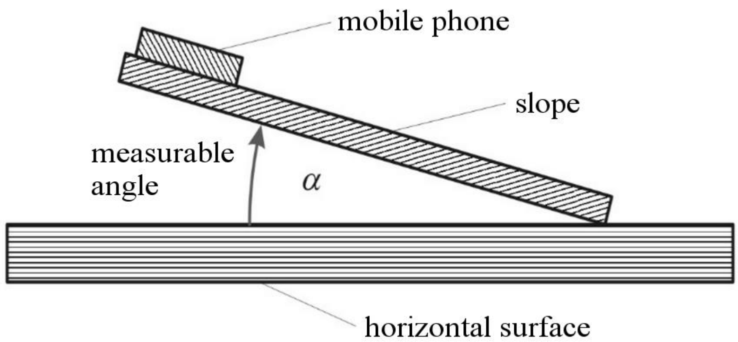

Fig.1. Using a smartphone in an experiment to determine the static friction between two different surfaces

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.

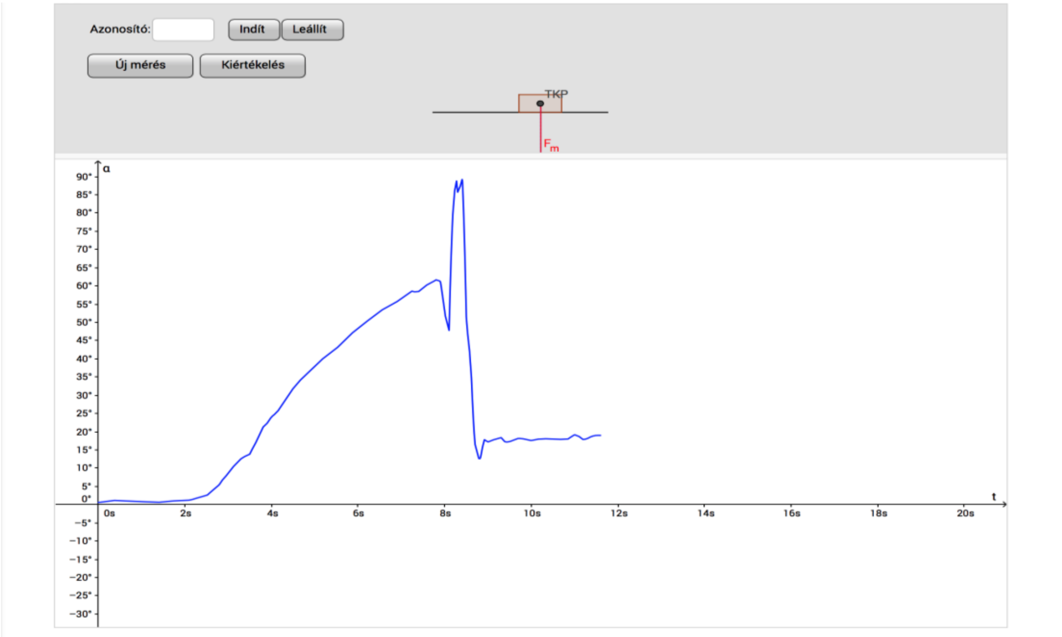

Fig.2. Real time data plot with GeoGebra and Geomatech Sensors

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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LIGHT POLLUTION MEASUREMENT: A PROJECT WORK FOR SECONDARY SCHOOL STUDENTS

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ABSTRACT

Our student group on environmental physics in Garay János Grammar School in Szekszárd started to show interest in light pollution, by reason of necessity of dark sky for our astronomical observations. In the frame of a project work we made measurements with a special portable photometer (SQM) in a nearby area in Tolna county called Hegyhát. We obtained very good data, approaching those of Hungarian International Dark Sky Parks' values.

INTRODUCTION

The Zselic National Park was the first in Europe to win the title of International Dark Sky Park on 16 November 2009. This title was founded by the International Dark Sky Association after realising that there are fewer and fewer places on Earth where the starry sky can be seen in its full beauty.

A hundred years ago every child could naturally experience the Milky Way, falling stars or constellations. However, gaining such experiences today is impossible without outings to places free from light pollution (Fig.1.).

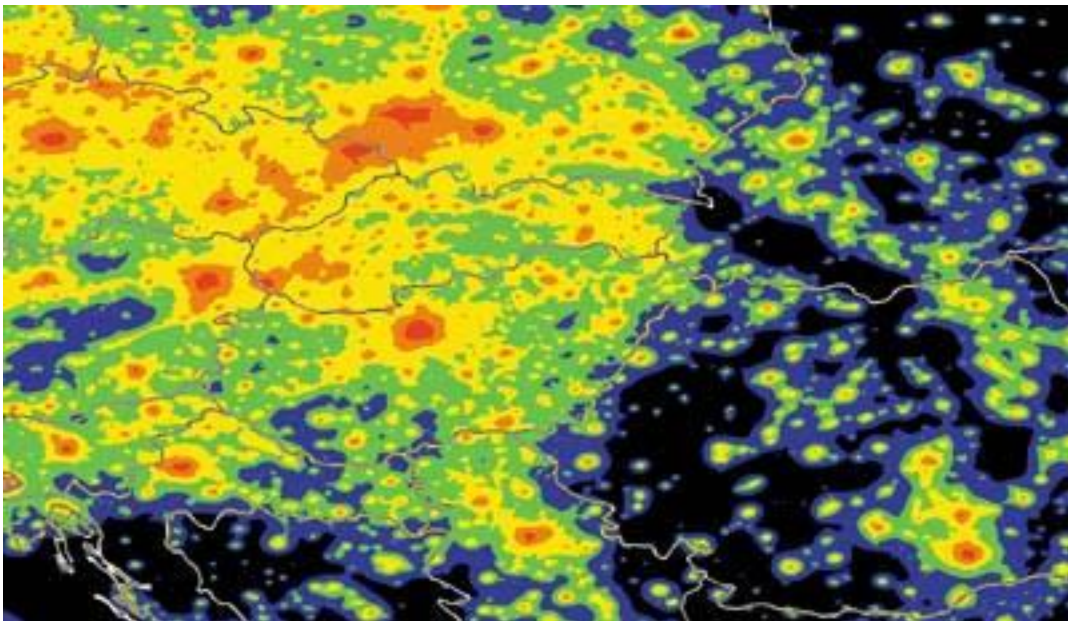

Fig.1. The map of light pollution in Hungary.

Together with some enthusiastic students we wanted to find out about and objectively justify by measuring whether there are places either in the neighbourhood of our school Garay János Grammar School or in Tolna county where the sky can be seen the way it is in Zselic. Our school successfully applies for micro researches and the necessary financial support every year within the frame of "Út a tudományhoz" (The Way to Science), which is a part of "Útravaló" (Provisions) Scholarship Programme. Due to our latest research programme (Shooting with Astrophotographic Mechanics) we got a good quality astrophotographic stand (EQ-6) with the help of which we were able to take highly aesthetic scientific photos of objects in the sky. For photos rich in details we had to find places with dark skies because the darker the sky is, the longer exposition time the photo requires and the more details can be seen in it. Finding such places was our reason for starting to measure sky brightness. Meanwhile, on the Internet we found a map showing light pollution in Hungary (see Fig.1).

The International Starry Sky Parks of Zselic and Hortobágy can be seen well in it and so can the sandy area of Illancs and the hills of Tolna the object of our measures. The lighter the colours are in the map, the shinier the sky is, and the darker they are, the higher quality the sky has (the darker it is) in that area. In the map we could see that the hills of Tolna may have sky similar to the quality of those of Zselic and Hortobágy the two International Starry Sky Parks. We planned to get ground-based measurements to prove this hypothesis.

LIGHT POLLUTION

Light pollution is in fact a skyglow, an increased light density on the nocturnal sky which originates from the artificial light at night scattered on the aerosols and molecules in the atmosphere. Fig.2 indicates that the incorrectly designed and installed lighting devices can be sources of light pollution if their light goes not on the right place, right time and not with the right intensity.

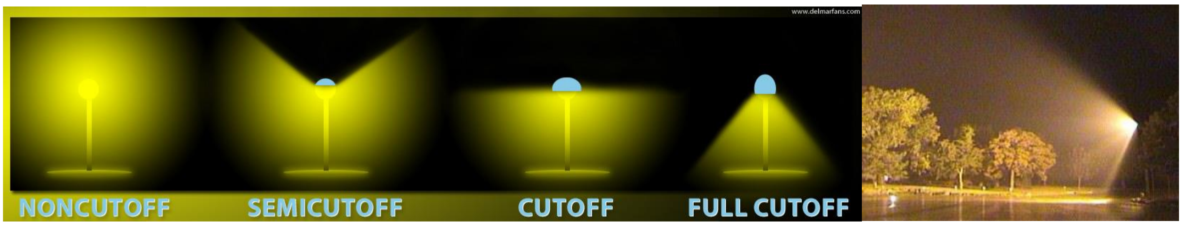

Fig.2. Light pollution sources. Left panel: possible design of the public lighting.
Right panel: badly installed lamp

These light sources have a high ULOR (upward light output ratio) value meaning that they spill light above the horizon. The wasted luminous flux causes energy loss, artificial skyglow, panorama destroying, undesired effects on health (including humans and other species) and dazzling.

Artificial light at night increases skyglow, that is why the astronomers and anyone else cannot observe less intense objects and phenomena of the nocturnal sky. Nocturnal artificial light sources (public lamps, illuminated flat houses and church towers etc.) disturb the flying insects', birds' and turtles' ability to navigate or to reproduce properly. Some nocturnally active species (for example bats or owls) or inversely, the daytime active species (for example the songbirds in the cities) cannot live their natural lifestyle because of the light pollution.

Nowadays most of the human beings live in unnatural light conditions. We spend our daytime period at less illuminated indoor places than natural outdoor illuminance, in addition, at night we cannot experience complete darkness. Our endogenous circadian rhythms are affected, for example body temperature, heart rate and melatonin production. With the artificial light we have altered the natural 24-h light-dark cycle, thus we can observe serious pathophysiological repercussions. Disorganization of our circadian system and perturbations in melatonin rhythm (caused by sleeping with artificial light, use of LED screens at night, shift work, jet lag etc.) denote an increased probability of the development of diabetes, obesity, heart disease, premature aging and some types of cancer [1].

Dazzling represents risk mostly for the traffic and for employees working in dangerous scopes of activities. If the light sources with high ULOR value emit too much light directly to the pupils, it causes temporary sight decrease because of the eye's inability to adapt to the new lighting level. Light pollution can be disturbing in one's property, for example if the incorrectly settled public lighting causes too much brightness in one's room so one can not sleep properly.

OUR MEASUREMENTS

We used a UNIHEDRON Sky Quality Meter instrument to measure the luminance of the sky. This small portable instrument has been used in Hungary for measuring the sky brightness since 2007. The device measures the average luminance of a 1.5 steradian solid angle towards the zenith. The unit of measurement of sky luminance is mag/arcsec^2, which can be converted into cd/m^2 (SI units) using the following formula:

$$\text{Value (cd/m}^2\text{)} = 10.8 \cdot 10^4 \cdot 10^{-0.4[\text{value(mag/arcsec2)}]} \qquad (1)$$

The temperature-calibrated device works with the precision of 10 percent in linear luminance (cd/m^2) units [2]. There are two types of this instrument (SQM and SQM-L) used in practice. The difference between them is in the angle of collecting light (see Fig.3).

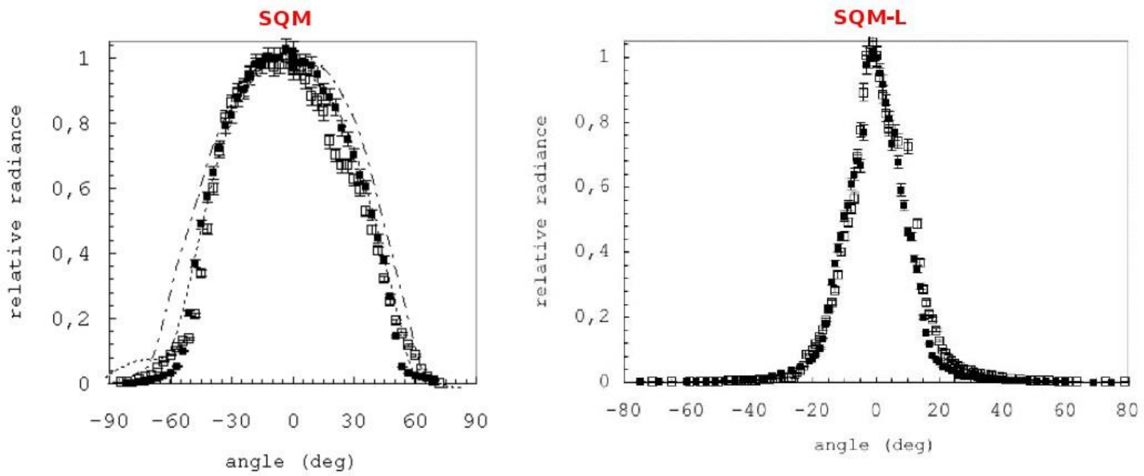

Fig.3. Solid angles of the two types of SQM.

An SQM works with a bigger angle, measures and counts the average of the thickness of the incoming light quantity. An SQM-L does the same but with a smaller angle. All of our measurements were taken with the device pointing to the zenith with an SQM-L to avoid the effect of the disturbing lights of Szekszárd on the horizon.

The favourable conditions for measuring are complex. It can be started when the night sky is clear without the Moon and the Sun is 18 degrees under the horizon, and should end before the Sun approaches the horizon up to 18 degrees again during its way at night. As long as it is possible, artificial sources of light should be avoided. When measuring in the town this condition is imperfect in some cases. Places with objects in the area such as trees that can disturb the detector of the instrument must also be avoided. Directing the instrument towards the zenith five measurements are made, the first two of which are ignored when evaluating them. These are less accurate data due to the time necessary for the instrument to warm up. The other three data are then averaged. The co-ordinates of the venues of the measurements are fixed by a GPS.

Fig.4. The members of our study circle while measuring.

Certification of the instrument was done with the help of calibrated SQM instruments gathering accurate data on the sand hills of Bácska in the area of Illancs, which is highly free from light pollution. We got evidence that no correction is needed as our instrument measures sufficiently accurately. We measured (Fig.4.) night sky brightness in Szekszárd at places relatively distant from each other. Later during our night outings among the vineyards we surveyed the neighbourhood of Szekszárd as well. A couple of times we drove along different routes in the hills and stopped at places to measure (Fig.5.).

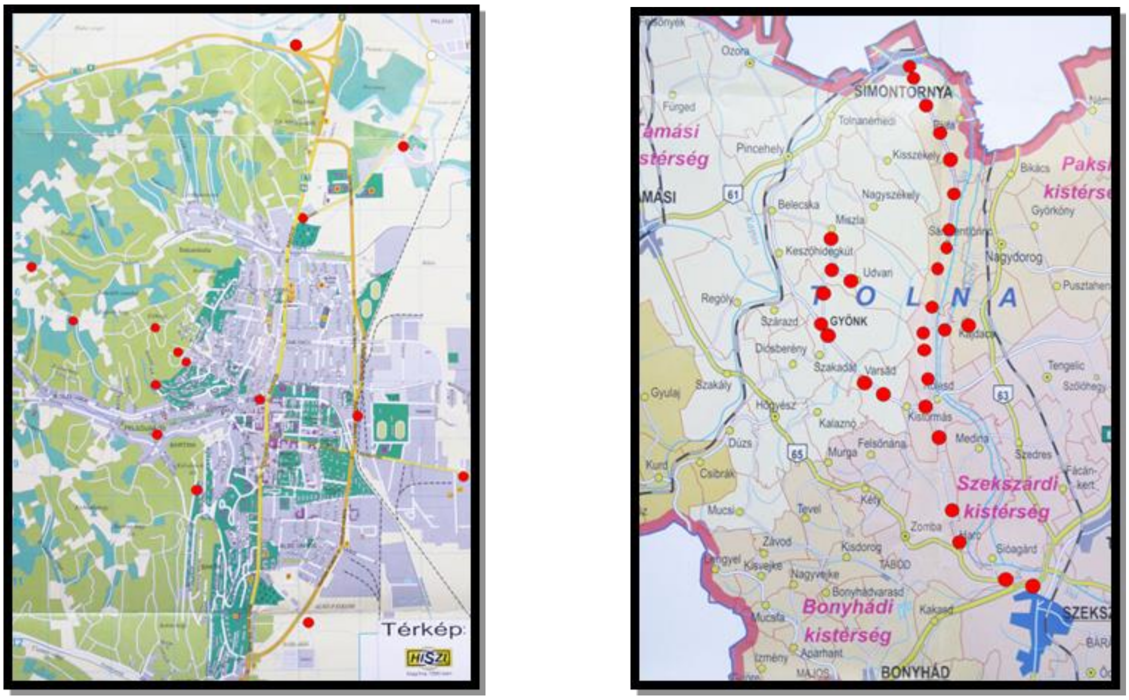

Fig.5. The venues of our measurements. Left panel: Venues in Szekszárd.
Right panel: venues in the hills of Tolna.

Quite a few factors made our measurements in the summer holiday difficult. For example, nature in the first place, the unpredictable weather, the late sunset and the early sunrise.

Because of these latter ones we had to make our measurements in the middle of the night. Besides, other tasks of the students, family holidays or the fact that getting to more distant points of the county is only possible by car also delayed our work.

DSLR PHOTOMERTY

After finishing our measurements in the summer of 2014, public lighting system has been refurbished in Szekszárd. The old high pressure sodium lamps were replaced with white energy-efficient LED lighting. Our research team from the university measured the luminance of the light dome of Szekszárd by DSLR photometry before and after the reconstruction. We used calibrated DSLR cameras with fisheye lens to get images with high ISO setting and long exposure time. Our photos in raw format can be converted to false colour images to show the distribution of sky luminance. With this method we could qualify different lighting systems and draw attention to the possible environmental effects of the changes in lighting. As Fig.6 indicates, we obtained a decrease of the sky brightness in Szekszárd [3].

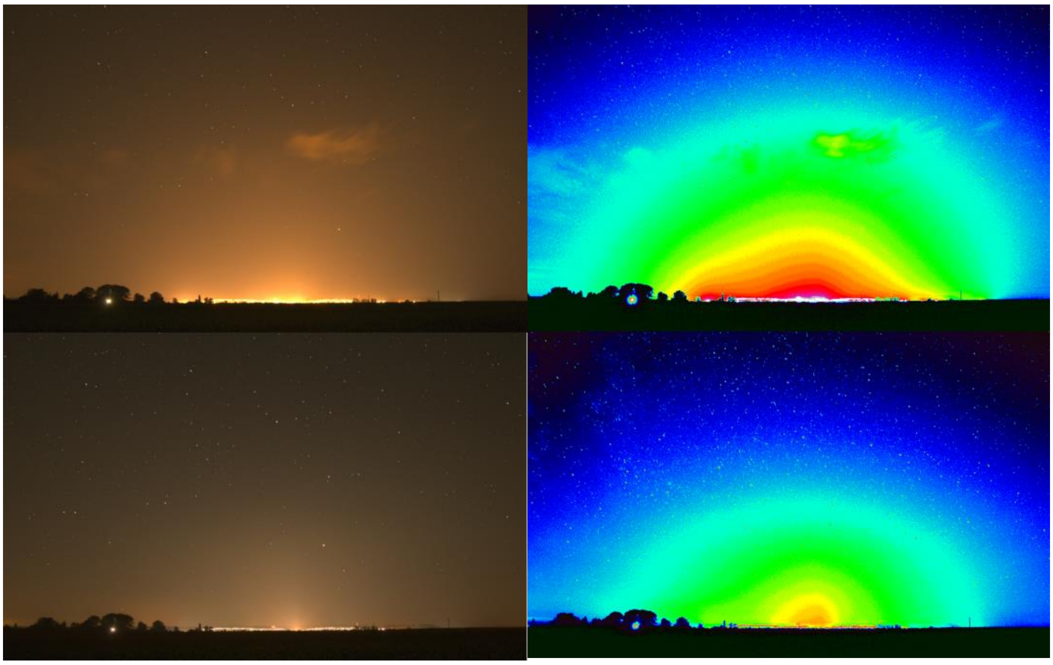

Fig.6. Light dome of Szekszárd. Top panels: before the reconstruction, bottom panels: after the reconstruction. Left panels: normal images, right panels: false colour images (Source: Z. Kolláth).

OUR RESULTS

As it can be seen from the data below our SQM measurements showed that the quality of the night sky of the hills in Tolna County is similar to those of the dark sky parks of Zselic and Hortobágy.

Table 1. The measured data.

measured areas	SQM-value
The average of the area of Szekszárd without the centre	20.4
The edge of Szekszárd at the vineyards	20.6
The average value of our measurements among the vineyards of Szekszárd	21.0
SQM-values in the area of Hortobágy Dark Sky Park	21.0 – 21.5
The SQM values of an all-night observation in the area of Illancs	21.0 – 21.5
The average of the measured values in the area of the hills of Tolna	21.1

CONCLUSIONS

The topic of light pollution proved to be an excellent project task. It was suitable to combine biology and mathematics, deepen the students' environmental awareness and last but not least the cooperation within the measuring team, their enthusiasm and the joy of learning playfully are all definitely serious pedagogic results. However, we find the pedagogic results more important than the physical ones. Now it is the students who want to continue measuring. We are going to take pictures of the hills of Tolna with DSLR photometry by our fish-eye lens bought with the help of application sources. It will be exciting to measure the sky brightness in the town and in its neighbourhood again with SQM after the public lighting changes.

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