THESIS OF THE PHD DISSERTATION

Applications of fluid physics and environmental attitude formation in high school Physics teaching

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Introduction

Physics of fluids is one of the most neglected topics in high school physics curricula. Examining the high school physics curriculum of different countries (Hungary, Romania, England, Germany, France), it can be concluded that in all cases the compulsory curriculum deals primarily with certain phenomena of fluid mechanics. Pascal's law, hydrostatic pressure, ideal gas law are discussed in all countries. In some countries the curriculum deals with surface tension and capillary phenomena (England, Germany). Atmospheric flow tends to be encountered by students only in relation with geography, usually without the explanation of physical phenomena. In the Hungarian curriculum, during the last two years, fluid dynamics is taught according to two different versions. Version A has an 8-hour frame, while Version B has an up-to-1 hour mechanics of liquids and gases. The Bernoulli law, the Magnus effect, the physics of swirling fluids (Karman-vortex series, Kelvin-Helmholtz instability) are not part of the curriculum in any country. However, more complex topics, that are more difficult for students, such as chaos theory, are included as part of the curriculum in Romania and Germany.

In addition to Astronomy and Nuclear Physics, students often mention nuclear physics and atmospheric phenomena when answering the question of what topics they would like to learn about during their studies of physics. Based on this interest and the opening of the curriculum to give the teacher a certain degree of freedom in the choice of topics, I try to introduce my students to environmental physics and, in particular, energy production and atmospheric flow in several ways. During my work on my PhD thesis, I explored the possibilities of this and developed teaching and extracurricular methods and practices in this regard. I used them in a high school in Transylvania with Hungarian as the language of instruction, where I primarily teach students of interest for sciences, with a 3-hour weekly course for four years, periodically supplemented by one hour per week for the teaching of Environmental Physics in 11th grade. The students are of average ability, with some exceptionally gifted students, 1-2 of whom continued their studies at the Faculty of Physics at Babeș-Bolyai University in Cluj-Napoca each year.

Aims

The main objective of my PhD research work was to interactively discuss the different topics of environmental physics (fluid physics, atmospheric physics, energy production) as an extension to the high school curriculum and thus develop an environmentally conscious attitude in my students. To achieve this, I set the following sub-objectives:

• development of alternative extracurricular activities (educational escape games, science fair

activities, environmental competitions) to discuss the physics of fluids and energy production by inquiry-based learning (IBL) methods

- analyzing green opportunities for energy production
- educating the conscious use of energy with the so-called energy panel-debate method
- developing an alternative curriculum for the optional subject
- engage high school students in scientific research with environmental physics research projects.

Thesis

1. Thesis: Applying escape room activities in physics teaching. I have developed educational escape room scenarios for experimental study of fluid physics. I first used these in extracurricular activities.

With the widespread popularity of escape rooms around the world, it was quickly discovered that it could be applied in education in a way to involve students' emotional commitment to the topic they are studying. As I have not yet met any activity developed for the physics of liquids, and have found it an excellent method for presenting the subject, I have developed and tried several series of exercises and experiments. I have shown that the method can be applied within a science museum setting where a single team is working in a closed room, but also in a student camp or other extracurricular activities where several teams are performing the same task in the same room.

The students had basic knowledge of fluid mechanics, which they could apply to the experiments. The topic was considered interesting and worthy of further study.

Surveys have shown that learning is more effective through active learning strategies, and an escape room activity is one such strategy. The activity is suitable for introducing a new concept, like surface tension, and for discussing the related phenomena phenomenologically.

In addition to the acquiring of subject knowledge, escape room activities can also develop skills such as complex problem-solving and communication (social) skills.

Publications related to the thesis: [1.], [2.]

2. Thesis: Comparing students with different interests and two teaching systems by the study of physics of fluids. I developed a new escape room activity for classroom use for a more difficult chapter of physics, the fluid flow. I have approached the phenomena mainly phenomenologically. During the testing I conducted surveys on six groups of students, which proved the success of the method.

I designed an educational escape room for classroom activity at level of grades 9 to 11, where students can study phenomena like Bernoulli's Law, Cartesius diver, and the Karman vortex street. The latter was analyzed by, among other things, using satellite imagery, so that students could encounter a large-scale atmospheric phenomenon.

The assignment was carried out by six groups of students of different ages and different interest for physics at Madách Secondary School in Budapest and Apáczai Csere János Theoretical High School in Cluj-Napoca. In connection with completing the exercise, students had the opportunity to express their opinion by unstructured qustionaire and completed a test. From these, it can be stated that during the one-hour activity students received a lot of information and understood the phenomena in a high percentage. The students of the two examined high schools performed similarly, there was no significant difference between the two groups. In the humanities profile classes, due to lack of interest in science and physics in particular, there is no progress in scientific thinking. For students with interest for sciences, the understanding of the observed phenomena has increased significantly due to their commitment to the subject.

Publications related to the thesis: [3.], [10.]

3. Thesis: Physics of liquids and atmospheric physics in science museums. I analyzed experiments presented in science museums related to the physics of liquids and atmospheric physics and their effectiveness depending on the mode of presentation. In the framework of the one-day physics fair called Experiment Saturday, I presented two experimental equipments, which introduce the modeling of several atmospheric physics phenomena. I suggest that these experiments be carried out and presented in permanent science museum settings.

Environmental physical phenomena present an exciting challenge for students as they are well-suited to their interest. Examining the science museums of different locations (England, Italy, Germany, Spain, Finland, the Netherlands, Hungary), we found very similar experimental equipment and that they

generally present the same phenomena.

The most common phenomena in science museums are the aerodynamics of objects of various shapes, the explanation of the Bermuda triangle, the representation of atmospheric vortexes on a spherical surface, the formation of smoke circles, the formation of a tsunami. In rare cases, we also come across means of presenting atmospheric fronts. The effectiveness of the experiments presented depends to a large extent on the mode of presentation.

I have developed three experimental settings that can be presented interactively in a science museum, which are not costly, but are not encountered in any of the playhouses I have studied. These experiments include studying soliton waves and weather fronts in a wave tank and a cylindrical vessel on a rotating plate for the Karman vortex street. For these experiments, I have developed measurement options that will keep the visitor's attention for a longer period of time and the attached description or, where appropriate, the animator will help to deepen and understand the topic. The experimental equipment was tested at the traditional Experimental Saturday at the Babes-Bolyai University Faculty of Physics, which aroused great interest and was, according to the feedback, one of the visitors' favorite experiments.

Publications related to the thesis: [4.]

4. Thesis: Comparative calculations of green energy production potential. I consider the possibilities of converting man-made energy into electrical energy. I have created a series of lesson questions that are suitable for analyzing the energy production of green conditioners and comparing it with traditional energy production methods.

As part of a two-hour teaching project, with my students I was exploring the environmental conditions where it can be beneficial to convert human-generated energy into electrical energy. At the same time, the emergence of green exercise rooms raises the question of whether this type of energy source can provide a solution to partially meet society's energy needs. Our calculations show that producing this very small amount of energy would require costly infrastructure to produce large quantities. I have shown that in this way the students become more familiar with the units of energy production and are able to make comparisons between the different methods of energy production. The activity promotes more conscious energy consumption.

Publications related to the thesis: [7.]

5. Thesis: Panel debate on energy production in education. I have developed a specific energy debate methodology, whereby students analyze the different energy production resources and their impact on the environment. In recent years, students in the energy debate have completed an attitude survey questionnaire at the end of the series to check the effectiveness of the method.

I have created my own method of teaching energy production problems: the energy debate. This is a role-playing educational method where students learn about the different sectors of energy production and the individual energy sources and analyze their environmental impact. One of the main problems of modern society with increasing energy consumption is how to make energy production more environmentally friendly. I used some elements of the debate program to develop the method of energy panel debate. When discussing environmental problems, I think it is important for the student to come to a conclusion based on the analysis of specific information related to their own living environment. This is what I want to do by choosing the topic of the debate: Discussing Transylvania's energy strategy for the next 25 years. At the same time, my goal was to enable my students to filter out misconceptions and potential pseudoscientific information related to energy production. I assessed the knowledge concerning energy sources and energy production of a sample of 9-11th grade students in a representative high school. I analyzed the misconceptions they had developed. I developed the method mainly for upper grades (11th and 12th), because I think it is important for the students to be able to create systemic relationships between acquired information.

As a conclusion to the debate, students express their views on what percentage of the various energy sources would be acceptable and feasible in Transylvania for a maximum of 25 years. By the analysis of data provided by students participanting in the energy paneldebate and a control group during several years, I have shown that the method succeeds in overcoming some of the misconceptions and creating in students a more realistic picture of the difficulties and consequences of switching energy production to renewable sources. I paid particular attention to the change in students' attitudes towards nuclear energy. Comparison with the control group shows that there has been a significant shift towards the acceptance of nuclear energy due to energy debate activities.

Publications related to the thesis: [5.], [6.], [8.]

6. Thesis: Talent identification through an environmental competition. Atmospheric phenomena and concepts related to the physics of fluids were presented to the students participating in an

environmental science contest with an empirical approach. I demonstrated that by this contest it is possible to identify gifted students for scientific research.

In the development of the students' environmentally conscious attitude, I consider that the possibility of direct experience by doing outdoor experiments is of importance. To achieve this, I have been involved in organizing environmental competitions since 1999. The methodology of organizing the contest is described in detail in a separate publication, which is available to all interested parties. Based on an initiative, this competition methodology that we invented will be introduced in Debrecen as well.

Atmospheric phenomena and the study of our rivers play an important role in the competition. I analyzed the efficiency of some experimental tasks (measuring the velocity of flow of a stream, determining the flow rate, and measuring the altitude difference detween two points with the help of a barometer). I found that in the course of the contest, students preferred field-based experimental tasks over theoretical computational tasks.

Publications related to the thesis: [8.], [9.]

7. Thesis: Talent development through student research projects. One of the important tools for developing students' creativity and commitment to physics is their involvement in research projects to study phenomena that are close to them or challenging. Research on this topic can even be seen as an interdisciplinary project, as it is a seemingly simple description of a complex system that requires computer simulations.

In recent years, there are several excellent opportunities (High School Student Conference - TUDOK, Science Contest of the Természet világa magazine, Youth Science and Innovation Competition, National Science and Technology Student Creativity Exhibition - OTTDK, International Conference for Young Scientists - ICYS) where students can present their research results and develop their practical skills by preparing for these competitions. Taking advantage of these opportunities, I have prepared 16 students on a variety of topics related to environmental physics over the past 15 years. The students' inclination for research work is primarily based on the exact and enthusiastic work of the students in the experimental activities, the quality of the questions they ask in the curriculum, and their persistent ability to work. When choosing a topic, it has proven to be extremely important for students to have a topic that is close to their own environment and their everyday experiences, so that their commitment to it can be stronger. I have shown that suitable topics include hearing loss due to young people's listening habits,

thermal comfort in residential and school buildings, dust pollution in classrooms, and modern environmental improvements such as hovercraft, magnetic levitation trains and environmental physics such as studying the propagation of soliton waves. I have developed a methodology for research projects, which facilitates the acquisition of research methodology. It turned out that these projects clearly influenced students' career choices.

Publications related to the thesis: [8.]

8. Thesis: Elements of new Environmental Physics and Geography optional subject. In order to extend the students' knowledge on physics, I have developed an optional course that approaches environmental physics, in which students are particularly interested, using interactive methods. The curriculum was developed based on some similar curricula and student feedback.

Although we rarely deal with environmental physics in high school physics courses, this is one of the most popular topics to learn about as a supplementation of the curriculum, in accordance with student opinion polls. That is why I developed a 35-hour course in Environmental Physics and Geography for 11th grade. The subject covers atmospheric phenomena (Coriolis effect, Hadley cells, running current, cold and warm fronts, optical phenomena in the atmosphere), environmental pollution, ecological footprint, solar constant, types of energy sources, analysis of energy production. The aim of the course is to broaden the topics of physics teaching with cross-cutting topics in which students need to apply the different chapters of physics and, at the same time, to help to develop students' environmentally conscious attitudes and to raise awareness of the environmental impacts of energy production. During the course, I put the emphasis on the Inquiry-Based Learning method (IBL), where students can get to know the above topics individually or in groups and present them to their peers. Part of the subject is the energy debate, which I present in detail in Thesis 5.

Publications related to the thesis: [6.], [8.]

Applying the results and further plans

The findings presented above, briefly described in my PhD thesis and in my publications, have provided some opportunities for the approach to fluid physics and energetics through classroom or extracurricular activities in high school. The methods, worksheets, programs of student research club and science contest have been worked out over many years and then developed and improved based on my experience. In practice, I have tried the methods described in the dissertation with students several times, and I have successfully applied them in other schools and city events. In my experience, students use these methods and activities to relate physical phenomena more closely to everyday life. At the same time, a deeper understanding of environmental physics plays an important role in shaping their scientific worldview. In this way, a more environmentally conscious attitude can be achieved. The majority of students participating in the student research club chose a career in engineering and science.

I would like to continue my professional methodological research in the future. I would also like to develop educational escape room activities on traditional topics of physics, and would do a comparative study on its effectiveness against conventional methods. If the planned Cluj-Napoca science museum is to be realized, I would like to put into practice the experimental tools on fluid flow presented at Experimental Saturday to provide the visitors with a real experimental experience and lasting knowledge. We hope that the soon-to-be-released curricular regulations in Romania will allow the expansion of environmental physics curriculum and its recognition at a broader, national level, so that this experience becomes a public good.

The publications underlying the theses listed in the order of mentioning

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2. Vörös, Alpár István Vita (2019) Szabadulószobák a folyadékok fizikájának tanulmányozására, *Fizikai Szemle*, LXIX, 2., pag. 58-63. oldal

3. Fülöp, Csilla; **Vörös, Alpár István Vita;** Sárközi, Zsuzsa (2019) Fluid Dynamics Knowledge Comparison of Students with Different Educational Background, *AIP Conference Proceedings*, beküldve 2019. szeptember

4. Vörös, Alpár István Vita, Sárközi Zsuzsa: (2016) Promoting Environmental Physics Issues in Science Centres and at Science-Events, *Teaching Physics Innovatively New Learning Environments and Methods in Physics Education, Proceedings of the International Conference Teaching Physics Innovatively (TPI-15),* Szerk: Király Andrea, Tél Tamás, Graduate School for Physics, Faculty of Science, Eötvös Loránd University, Budapest, ISBN 978-963-284-815-0, pag. 79-84.

5. Vörös, Alpár István Vita (2019) Panel-debate on Energy Production in High School Physics Teaching, Canadian Journal of Physics, special issue dedicated to Li-Hong Xu, beküldve 2019. július

6. Vörös, Alpár István Vita (2019) Outcomes of an Optional Environmental Physics Course in High School, *AIP Conference Proceedings*, beküldve 2019. szeptember

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9. Vörös, Alpár István Vita; Fehér, Judit; Irsai, Mónika; Gottwald, Márta; Kósa, Mária **(**2015) *„Fűért, fáért halljátok hát szavam…" Xantus vetélkedő módszertani útmutató*, Exit, Kolozsvár, ISBN 978-973-0-19571-2, pag. 7-23, 63-71

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11. Vörös, Alpár István Vita; Biró, Botond; Bartha, Vivien Emőke (2014) Ismert fizikai rendszerek számítógépes szimulálása, *A kolozsvári Apáczai Csere János Elméleti Líceum Évkönyve 2013-2014*, Exit, Kolozsvár, ISSN 2343-9165, pag. 54-62. (7. tézis)

12. Vörös, Alpár István Vita; Fehér, Judit; Pilbák, Enikő, Bárdos, László (2010) Suntem conştienţi de problemele mediului, deci ne pasă, In: *CO2nnect, CO_2 în drum spre şcoală*, Szerk.: Tóth Mária, Stúdium, Kolozsvár, ISBN 978-973-643-176-0, pp. 89-96. (8. tézis)

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3. Kiss, Ádám; Tasnádi, Péter: Környezetfizika, Typotex, Budapest, 2012
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