PhD Theses

TEACHING ATMOSPHERIC PHENOMENA IN A CLASS ORIENTED TO THE HUMANITIES
Lightning Flashes and their Effects

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I. Introduction

The knowledge and understanding of atmospheric phenomena and weather have been a human desire for thousands of years. The first records of observations date back to Ancient China and India. As farming appeared and broadened, weather observations became increasingly important as they determined the timing of sowing and harvesting and influenced the amount of the crops harvested. While Aristotle (350 B.C.) discussed in his Meteorologica, how thunder and lightning work, people still attributed supernatural power (Zeus, etc.)to lightning strikes due to the lack of scientific knowledge. Until the middle of the 18th century, people knew much about neither electricity nor the theoretical explanation of the electrical phenomena in the atmosphere. Amazing experiments in electrostatics were an inevitable part of social life, with performers dazzling the audience. In the middle of the century, many performers had already discovered a link between electric sparks and lightning, although they did not know how lightning works.

Lightning's research likely began with Benjamin Franklin. In 1752, Franklin performed his famous kite experiment and proved the similar behaviour of electric sparks and lightning. Scientific research to uncover the mysteries of this atmospheric phenomenon began only afterward due to the destructive effects of lightning. It remains a popular research field in geophysics, space science, and meteorology.

Lightning events which have kept people in awe for thousands of years, appear during thunderstorms. The devastating effects of lightning and the high publicity given to tragic accidents have increased public awareness of these phenomena.

II. Goals and methods

In the new Hungarian NAT (National Curriculum) introduced in 2020, the discussion of lightning, lightning protection, and the proper behaviour in thunderstorms have become compulsory parts of the physics curriculum. Until the introduction of the new Hungarian NAT, the discussion of lightning, lightning protection, and the proper behaviour in thunderstorms was only a supplementary part of the physics curriculum Since then, they have become a compulsory part of it. Difficulties can arise in their teaching due to the lack of sufficient teaching materials designed for high school students. Studying lightning discharges and their formation is very complex and challenging to discuss in precise terms in high schools because students are not familiar enough with higher mathematics and physics. (Moreover, many details of the topic are still unclear.) Therefore, the main goal of my research was to develop teaching materials using the MER (Model of Education Reconstruction) method, which would convey scientific knowledge in a way that students could understand and provide an attitude-forming surplus. I used elementary approaches to describe and interpret the phenomena. I have suggested some ideas to integrate the knowledge about lightning in several chapters of the physics curriculum to help the work of colleagues in the field.

In the last decade, students have shown less and less interest in science subjects, including physics. Therefore, during my research, I wanted to integrate modern techniques (web 2.0 applications, educational videos made by teacher candidates) into my lessons to support the MER method. I looked for ways to motivate students in physics teaching (flipped classroom, gamification, project method).

The changing needs of society and students require constant changes in education and physics teaching. Today's high school students are members of Generation Z (born between 1991 and 2010), accustomed to the rapid flow of information, and digitalization determines their daily lives. Most of the teachers who teach them come from Generation X (aged 42-61), with different background knowledge, traditions, learning, and teaching habits, and a different set of values. Bridging the generation gap and responding to the changing needs of society is a challenge for all members of education, requiring flexibility and adaptability. Our education can be successful if we bear in mind the words of John Dewey, the reformer of the American education system: "If we teach today's students as we taught yesterday's, we rob them of tomorrow." (John Dewey). In my research, I studied the possibilities for developing 21st-century key competencies, for implementing learner-centred education, for motivation, which also appears in several international programs and regulations (such as Partnership for 21st-century skills (P21), En Gauge, Assessment and Teaching of 21st Century Skills (ATCS), National Educational Technology Standards (NETS), and the National Assessment of Educational Progress (NAEP) (Voogt, Roblin, 2010)). In the literature, these skills have become known as the 7Cs. They are Critical thinking, Communication skills, Collaboration skills, Creativity, Computing and ICT literacy, Cross-cultural understanding, and Career and learning self-reliance.) The appropriate application of modern technology in education is inconceivable without professional knowledge, knowledge of technical tools and their potential uses, and familiarity with innovative pedagogical methods. Therefore, over the past five years, I have participated in several teacher training courses at home and abroad, where I have acquired the theoretical basis of modern technologies (web 2.0 and other multimedia tools) and pedagogical methods ("flipped classroom" PBL, IBL, DBL, peer teaching), and have become familiar with good practices on an international level. The job shadowing activities (one-week school visits to England, Norway, and Spain) gave me insights into the practical application of the methods and ideas for integrating them into my teaching practice.

Based on the TPACK model (Technological Pedagogical Content Knowledge), I studied

- the possibilities of using web 2.0 tools in physics classrooms,
- the role of educational videos showing basic experiments in learning,
- the new dimensions of education through social networking platforms and project pedagogy.

III. Students participating in the research

The students of the Szabó Lőrinc Bilingual Primary School and High School (my former school) in Budapest District II, grades 9-11, and the Vörösmarty Mihály High School (my current school, VMG) in Érd, grades 10-11, participated in my research. Some classes were bilingual in English, and some had a general curriculum. All of them learned physics in Hungarian. (Where bilingualism plays a significant role in the research, I emphasize it.) Each group consisted mainly of students interested in human subjects. They learned physics at an intermediate level, in 2 hours per week. There was no group separation in physics lessons, except in VMG, where the few students who chose physics as a faculty subject were separated from their classmates and studied physics in separate groups. Students participated in various phases of the research in different numbers. It depended on the research goal and the subject allocation in the academic year.

IV. Theses

Thesis No. 1

Teaching lightning activities using the MER (Model of Educational Reconstruction) conception [S4], [S5]

In my thesis, I have shown that the complexity of lightning makes it a splendid tool for developing complex scientific thinking. Exploring the links to other science subjects (geography, biology, chemistry), I have shown that teaching lightning is an excellent topic to implement curriculum integration. I created a booklet[i] for my students which I shared with them on the GC (Google Classroom) platform. In developing the teaching resources, I focused on understanding the phenomena. I followed the MER conception to transfer the scientific knowledge of lightning physics to the students. I used elementary approaches and simplifications in describing the phenomenon and explanations that do not affect the content.

Through my teaching experience and the student feedback, I have demonstrated that the materials developed can be used effectively in physics teaching, and the topic is highly motivating. I have made thought-provoking suggestions for integrating the basic concepts of lightning physics into the high school curriculum.

The topic of atmospheric electricity appears in the 10th grade in the new physics curriculum. Chapter "Sparks and Lightning" discusses the basic concepts and laws under the topic "Electrostatics" in the previous curricula. I have shown that explaining many phenomena concerning lightning goes beyond electrostatics. Understanding the details of it requires the discussion of lightning in other branches of physics.

As scientific evidence accumulates, the knowledge needed to understand atmospheric phenomena appears in a split way, related to disciplines. Students learn about the atmosphere, its changes, and atmospheric phenomena, especially in geography. Therefore, the descriptive character of the subject determines the method of negotiation. However, understanding the different mechanisms that explain the movement of charges in lightning and the different electromagnetic wave ranges of lightning is inconceivable without a basic knowledge of chemistry. Understanding the physiological effects of lightning requires a link to biology. I have shown that subject integration, knowledge transfer, and giving additional knowledge in physics can help students to gain a deeper understanding of these complex phenomena. They contribute to clarifying misconceptions attached to lightning. In my thesis, I investigated the teaching role of lightning flashes.

The chapter "Sparks and Lightning" plays a prominent role in high school physics teaching, as it introduces many concepts in electricity.

However, the abstractness of the concepts and the lack of the students' complex knowledge in higher mathematics and physics make the topic difficult to be discussed for students with less interest in physics. Although, the wonderful world of lightning and the dazzling light phenomenon of the upper atmosphere amaze them. Its connection to everyday life (lightning protection, physiological effects, localization of lightning, etc.) through the practical application of physics underlines the usefulness of physics knowledge and is an extraordinary motivating force.

However, the background knowledge required to understand the process of lightning and to describe the dangers of lightning strikes cannot be limited to the part of electrostatics.

Understanding more details of the topic requires discussions of lightning in other fields of the curriculum (magnetic induction, electromagnetic radiation). As a first step, I interpret the electric field of thunderclouds and its effect on the charge distribution on the earth's surface based on the simplified tripolar model of thunderclouds. I also investigate their role in the global atmospheric electrical circuit. Then I discuss the different forms of lightning flashes and their general features. I also cover the mechanism of lightning strikes, the basic principles of lightning protection, and the various impacts of lightning (especially the interaction of lightning flashes with humans). I also discuss the localization of lightning and the importance of forecasting as a practical application of the laws of physics. Teaching materials are created based on the following books V. Cooray: Introduction to lightning; Uman: Lightning discharges; Cooper, M. A., Andrews, C. J., Holle R. L., Blumenthal R., and Aldana N.N.: Lightning –Related Injuries and Safety and M. A. Cooper: Reducing lightning injuries worldwide several publications, and the e-learning course materials of MetEd (Meteorological Education https://www.meted.ucar.edu/index.php). I have tested all the materials in classroom activities in the last four years and modified them several times according to my experiences. I have also prepared methodological recommendations for using them. I have shown how to insert cognitive content concerning lightning into the different chapters of the compulsory physics curriculum.

Thesis No. 2

Schumann Resonances and Upper Atmospheric Electrical Discharges in high school Physics Education[S9], [S10]

I have created a teacher guide about upper-atmospheric electro-optical phenomena, especially for high school teachers. The material covers the phenomena in an elementary approach.

Based on students' feedback, I have confirmed that new scientific research focus areas and results, as well as fascinating video footage from various authentic internet sources, have captured the attention of those less interested in physics.

Studying the upper-atmospheric lightning and electrical-discharge phenomena goes far beyond the requirements of the core curriculum. Thus, the teaching material prepared can only be used as supplementary one. I suggest using it mainly in the context of workshops and theme weeks. The novelty and visual appeal of the topic makes it suitable for stimulating and sustaining students' interest in physics. The experiential discussion supports the promotion of today's scientific research methods and results. The description of the phenomena draws on the knowledge acquired in geography, chemistry, and earlier physics branches. Therefore, it promotes subject integration and contributes to the development of coherent scientific thinking. I tested the curriculum in three classes (84 students) in a classroom setting. In my thesis, I summarized the scientific knowledge based on the MER conception and presented the students' feedback.

Thesis No. 3

Flashes and misconceptions [S3],[S6]

There are still many misconceptions about lightning. I assessed *high school students in grades 9-10* on what they thought of these *commonly held misbeliefs. I had them repeat the test a year later after teaching. (The diagnostic and summative question sets were the same ones.) Based on the evaluation of the results, I have shown that the misconceptions are mainly due to a lack of basic knowledge to understand the phenomena. However, the fact that scientific knowledge of lightning is still incomplete and is still evolving and expanding. Sometimes one finds inaccurate or false information on different internet platforms and media sources. In many cases, there are no exact data, only eyewitness reports are available, but their authenticity is questionable (such as reports concerning ball lightning).*

For thousands of years, people have feared lightning strikes of unknown origin and enormous intensity, often attributing supernatural powers to them. Until the middle of the 18th century, the phenomenon was shrouded in mystery, as the nature of lightning and the conditions under which it occurs were unknown. It may also have been the source of many myths related to lightning. I have collected especially those misconceptions attached to lightning protection and the impacts of lightning on humans. I studied the physics conceptions and laws behind them and incorporated them into the teaching materials. In my dissertation, I evaluated the results of the students' tests and analysed the proper behaviour in lightning risk situations.

Thesis No. 4

Video tutorials showing experiments are fruitful tools for modern physics education [S2]

I have shown that educational videos are fruitful tools of high school physics teaching in both online and traditional (face-to-face) remote environments. I focused on easy-to-do physics experiments relevant to the high school physics curriculum. I examined YouTube-type videos of 3-6 minutes with captions, explanatory diagrams, and attention-grabbing signs produced by Canadian teacher candidates.

Performing experiments is at the core of physics teaching. In my thesis, I investigated the potential use of educational videos in high schools. These videos, created by future teachers show experiments requiring limited special equipment. They do not substitute for the live ones but can supplement in-class instruction and learning at home. An outstanding value of educational videos is that they always include short explanations of the experiments that illustrate the phenomena. As a member of the MTA-ELTE Research Group on Subject Pedagogy, I participated in an international research project with Prof Marina Milner-Bolotin (University of British Columbia, Vancouver, Department of Curriculum & Pedagogy). We examined a pedagogical intervention that uses science videos to improve future physics teachers' experimental and pedagogical skills. During the joint work, I was responsible for keeping in touch with the Canadian partner, coordinating the production of the domestic educational videos, testing the selected videos with high school students, evaluating the results, drawing conclusions, and making recommendations for their use. I chose two topics (Geometric Optics and Waves and Sounds) to test the videos. In total, 101 students (14-17 years old) participated in the study. In each group, I used a different pedagogical approach that incorporated the videos to examine their effectiveness in supporting students in self-directed learning and to keep them engaged and motivated. I compared various pedagogical approaches by analysing student responses to the pre-and post-tests. I confirmed that educational videos could be used effectively in physics teaching by formulating guided teacher questions to increase student activity.

Thesis No. 5

Widespread use of Web 2.0 applications in physics lessons [S1], [S8]

The changing needs of society to effectively educate and prepare Generation Z students for their future careers also require the digitalization of physics education. As for me, applying both traditional and digital tools and methods is significant to be successful in teaching. It is also necessary to get the perfect balance between them to preserve the richness of the content in physics. I have shown that the widespread use of Web 2.0 applications increases student engagement in learning and the effectiveness of physics teaching. They also improve several 21st-century competencies. I have demonstrated that incorporating gamification into lessons makes them more enjoyable. Competition among peers increases students' motivation.

Today's Generation Z high school students are eager and confident in using ICT (Information and Communication Technology) tools in their learning process, including web 2.0 applications. (Web 2.0 applications are a set of web applications and services that are highly interactive.) In my thesis, I have demonstrated that web 2.0 tools can be effectively used in high school physics education, complemented by modern pedagogical approaches. By increasing student activity and integrating elements of gamification, they can also be motivating for students less interested in physics.

I compared the learning outcomes in the experimental and the control groups using a series of summative tests on three topics (Electric Field, Magnetic Field, Vibrations, and Waves). These tests were aligned to the requirements of the intermediate level of the baccalaureate and consisted of multiple-choice, simple arithmetic or true/false, and reasoning tasks. The control group used traditional methods and forms of work, and the experimental group used a wide range of web 2.0 applications and modern pedagogical methods (flipped classroom, inquiry-based learning, gamification) and collaborative forms of work. I also investigated how to use applications to facilitate collaboration and communication among students inside and outside the classroom; how they support the development of skills expected by modern society (such as critical thinking; creativity; digital literacy; communication, problem-solving, and collaboration skills). At the end of the academic year, I also examined how the student's attitudes toward physics had changed. I asked them to rate the use of apps in physics lessons on a scale of 1 to 5 according to predefined criteria. (It went from 1, the lowest rating, to 5, the highest rating)

The students positively accepted the use of the new tools. They found that the apps were useful in self-learning and helped them to understand abstract concepts and acquire basic knowledge. The social platforms opened new dimensions in the learning process in space and time. The uploaded materials supported them in preparing for the assessment. They welcomed personalized teacher feedback and evaluation through the social networking platform.

Thesis No. 6

New dimensions of Physics education: combining socio-scientific issues and project Pedagogy in physics education [S11]

Integrating socio-scientific issues in physics curricula (such as global warming and its impacts, energy management, nuclear energy use and risks, biological aspects of radioactivity, and others) and their combination with project pedagogy is an effective tool to motivate students. In addition to raising awareness, the thematic approach supports education for sustainability, *raises awareness of environmental values, and develops competencies for action on environmental and sustainability issues. Applying modern technological tools and other pedagogical methods (such as web 2.0 applications, online social networks, video conferencing, PBL project pedagogy, IBL, and others) enhances the effectiveness of the teaching. Moreover, they develop several key 21st-century competencies (digital, collaborative, problem-solving, foreign language, intercultural, and others).*

Physics teaching aims to develop problem-solving skills, critical thinking, and scientific literacy, in addition to the transfer of scientific knowledge. Integrating socio-scientific issues in the physics curriculum provides an excellent opportunity to do this. Studying these global problems, as they affect several areas of our daily lives, can motivate learners. Addressing environmental science, sustainability, and other global issues requires recalling knowledge from different science subjects. Due to their interdisciplinary aspects, they can serve as a starting point for small or large projects. Beyond sensitization, there is a societal expectation that modern man should be able to form a critical and intelligent opinion on these issues and, if necessary, take action to reduce environmental damage, for example. The acquisition of basic knowledge of the natural sciences is a prerequisite for this. In addition to sensitization, at the societal level, it is expected that modern man should be able to form an opinion critically and intelligently on these issues and, if necessary, take action to reduce environmental damage. The acquisition of basic knowledge of the natural sciences is a prerequisite for this. I presented our Erasmus+ project, working with the Borgarholtskol High School in Iceland, as a good practice in physics teaching. We studied harnessing hydropower and geothermal energy in the two countries. The name of our project was "Our natural treasure: water" During the joint work, the communication among the participants took place through a social platform. We used blog posts, chats, video conferences, and social networks to coordinate students' activities. We also shared students' video clips, photos, quizzes, questionnaires, and presentations. We used various pedagogical methodologies and modern technologies during the project. The students' environmental awareness developed during the preparation, implementation, and evaluation of their activities in the project. The most significant indicator of the project was its expansion to the school scale, and its main strength was the process of thinking together about the shared activities and experiences.

Publications related to the Theses

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3. I Takátsné Lucz and P. Tasnádi, How to teach lightning activities to spark students' curiosity? Adv. Sci. Res., 19, 137–144, https://doi.org/10.5194/asr-19-137-2022, 2022.

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