Journal of Applied Technical and Educational Sciences jATES

ISSN 2560-5429

http://jates.org

Role of global environmental issues in Hungarian physics education

Zsófia Nógrádi [1,2*], Tamás Weidinger [3]

[1*] *Cházár András street 10, 1146 Budapest, Hungary, ELTE Radnóti Miklós Gyakorló Általános Iskola és Gyakorló Gimnázium, nogradi.zsofia@radnoti.elte.hu*

[2] *Pázmány Péter street 1/A, 1117 Budapest, Hungary, ELTE Doctoral School of Physics, Teaching Physics Programme*

[3] *Pázmány Péter street 1/A, 1117 Budapest, Hungary, ELTE Institute of Geography and Earth Sciences, Department of Meteorology weidi@staff.elte.hu*

Abstract: *The choice of topic was important to show that it is possible to do environmental physics in this few science lessons we have, while doing projects in class or outside of class. Projects that can be used and tested in secondary school's physics lessons are presented, with environmental education as one of the objectives. An important feature of the projects is that they can be integrated into the physics curriculum and support the learning and use of modern skills. Examples of such skills include collaboration, internet awareness, data analysis, research approach and interdisciplinary thinking. The main aim of this article is to present some of the projects that have been tried out in physics lessons, which have been effective in raising environmental subjects and have also been used as motivational activities. As a result of the projects, an increase in students' motivation towards both physics and specific aspects of nature conservation was detected.*

Keywords: *environmental education; physics education; project-based education; developing 21st century competences*

1. Introduction

Environmental education also found a place in the education system of post-war Hungary, in 1970, and was further elaborated in 1990. It was also included in the central law regulating the education system, the 1995 National Basic Curriculum (Lenches, 1998; Ballér, 2003). With the creation of the framework curricula in 2001 it was included in the basic curriculum and it plays an increasingly important role, primarily an attitude-shaping role, in the Hungarian education system (Kónya, 2018). This is also reflected in the teaching of physics. Examples of this are shown in the context of small group activities and school projects in grades 7-10. The combination of everyday life questions and the exact knowledge of physics helps to develop scientific cognition, strengthen problem-solving skills and help to answer questions that often seem distant.

We begin by addressing the importance of environmental education, both in education and in understanding the problems of everyday life. Then we will analyse the place and role of environmental education in physics education, followed by a presentation of the projects and good practices we have developed. We will also look at good practice abroad.

2. Hungary's education system today

Since 2005, the country has had a two-tier school-leaving certificate system, which means that you can take either the intermediate or the advanced level. The range of subjects is expanding, including specialised subjects and foreign languages, but all students have 4 compulsory subjects, Hungarian language and literature, mathematics and history, and a foreign language. Apart from these, there is no limit to the number of subjects a student can take. There is no limit on the number of subjects that can be taken, except in the final year, in science subjects after the end of the subject, as well as in digital culture. In addition, if the school offers a foreign language as an additional subject, it is also possible to take foreign languages from year 10 onwards, after the end of the school exams.

The most typical type of school in Hungarian public education is the 8-year primary school followed by a 4-year gymnasium or 5-6-year vocational gymnasium. Admission to primary school is generally linked to the place of study, and there are few primary schools that link admission to the school to admission. However, after primary school, students have to take entrance examinations and are then admitted to the type of school of their choice. Secondary schools prepare students primarily for higher education and for the school leaving certificate, while vocational schools prepare students for the school leaving certificate, but they have already specialised their studies and take a vocational examination on leaving school. After finishing primary school, those who do not go to university can continue their studies in a vocational school, where they have to learn a specific trade (Nagy, 2018; Eurydice, 2023).

In the case of a 12-year grammar school, students stay at the same school for the rest of their studies before university, while in the case of an 8-year grammar school, they attend a single primary school for 4 years and then, after admission, they are admitted to a grammar school where they continue their studies until they graduate. There are 6-year grammar schools, where the first 6 years are a normal primary school year, after which they are admitted to a preparatory year of language study, during which they study one foreign language for a larger number of hours, while the other subjects are levelled up. The school where I teach has 12-, 8- and 6-year high school classes. Our school is a practising school, which means that our teacher training students observe classes and do their practicum under the guidance of mentor teachers before they graduate.

The operation of these types of schools is unified by state legislation, known as the National Curriculum, currently the 2020 curriculum, which is being introduced in a progressive system. According to this legislation, physics is taught from grade 7 to grade 10 for all pupils not attending a vocational school. In the last two years of secondary school, students may choose to continue their studies in physics as an optional subject. The faculties prepare students for the upper secondary school-leaving certificate and for further study at university.

There are also alternative private schools, such as Montessori or Waldorf, which have their own rules.

~~Most countries in EU, compulsory schooling starts at the age of 6 or 7, which is also the age at which Hungarian children start school, but they are obliged to attend kindergarten from the age of 3. The tripartition of the school system (primary, secondary and upper education) is common in all European countries, but is linked to different age groups and time intervals. Where there is a significant difference is in the annual school workload, in Hungary, this is on average 600 hours per year, which is low compared to the European average, but not significantly different compared to the Central and Eastern European average. (Eurydice, 2023)~~

3. Presentation of project pedagogy and its relevance to teaching about the environment

The school activities described below are project-based, and an important part of their design is to ensure that the educational process is one in which both community and individual development are reflected. A fundamental part of the projects is the transfer of values, which, in addition to the application and practice of the lessons learned, also means raising awareness of environmental problems and possibility pf harm reduction.

As an educational strategy, project-based learning requires an activity-based model that goes beyond the school setting, where learners are responsible for their own learning. The National Curriculum of 2020 also emphasises the importance of problem-based thinking and sets as a key objective that students should not only be passive recipients of learning, but also active participants and shapers. The curriculum combines the development of problem-solving thinking with collaborative and creative teaching styles.

The local curriculum identifies as an important task the development of students' scientific understanding, which includes critical interpretation of resources and active use of the concepts learned (K. Radnóti and F. M Adorjánné, 2013).

The main aim of the sample activities is to educate people to think and act in an environmentally aware way, and to assess their own and others' responsibility for their environment and their future. The local curricula recommend project-based methods, problem-based teaching or experimental group work to increase pupils' motivation to work on environmental problems and develop skills.

One of the main results of György Pólya's research was the development of a theory dealing with the decision making process of problem solving (Gy. Pólya, 1969). This research is the basis of the PISA assessments, so it is not surprising that one of the main areas of focus in these assessments is complex problem solving thinking itself. In his study in 2005, Benő Csapó concluded from the results of the 2003 PISA surveys that problem solving as a skill is a key teaching task for public education (B. Csapó, 2005).

In his book on the practice of environmental education, János Lehoczky (Lehoczky, 1999) emphasises that the project method, collaborative learning techniques and out-of-school activities help to develop environmental thinking. In Lehoczky's statement, it is mentioned that the effectiveness of environmental education is enhanced by the experiences gained during the learning process and that goal-oriented activities help to deepen the learning that supports the use of project methods. As Mária Kováts-Németh writes in her article (Kováts-Németh, 2011), the teacher's task is not only to transfer knowledge and point out connections, but also to transmit values, standards and help to identify and solve problems. The importance of developing responsible behaviour and the effectiveness of using the project method are also highlighted in the Forest Pedagogy Project (Kováts-Németh and Földes-Leskó, 2019).

The above considerations support the view that the projects presented below are appropriate to the 21st century learning-teaching model and support the development of the skills that are a priority today, and increase students' motivation and engagement in learning the subject.

4. The role of environmental education in our daily lives and in education

In today's world, the 'monster of pollution' is everywhere, perhaps too often (Dodds, 2011; Marks et al., 2021). Environmental disasters are often highlighted in the media, but there is also a growing emphasis on environmental protection and sustainability (Kajner et al., 2013). This should be part of our everyday lives, as it was for our ancestors living with the environment for centuries.

The accuracy of environmental ambition is demonstrated by the fact that 8 out of the 17 targets in the 2030 Agenda for Sustainable Development include sustainability and the environment. The goals include sustainable agriculture (Goal 2.), sustainable water management (Goal 6.) and sustainable and modern energy access (Goal 7.), but there are also a number of goals that include measures to protect the environment as a whole, such as Developing sustainable consumption and production (Goal 12.), Taking urgent action to fight climate change and its impacts (Goal 13.), and Sustainable development (Goal 16.). Conserve and sustainably use oceans, seas and marine resources for sustainable development (Goal 14.) and Promote the protection, restoration and sustainable use of terrestrial ecosystems, sustainable forest management, combat desertification, halt and reverse land degradation and halt biodiversity loss (Goal 15.). (General Assembly of United Nations, 2015)

Of course, today's examples are different: more and more packaging-free shops are opening or plastic-free items are appearing in stores. For example, not everyone knows why we avoid food containing palm oil and not everyone goes vegetarian to protect the environment, but fortunately, ordinary people are increasingly finding ways to protect nature (see the problem of reactive nitrogen ("Nr"): Horvath, 2010; Sutton et al., 2011; Westhoek et al., 2015). These include, to take just one example, canvas bags in supermarkets, energy-saving electrical appliances and selective waste bins in shopping malls and public areas. Several surveys by the Hungarian Central Statistical Office (KSH) show that we have become more environmentally conscious in the 2000s, for example, the reduction in electricity consumption and per capita water consumption is partly due to this, alongside technological advances (KSH Environment Picture, 2018).

Few are questioned the prominent role of environmental education and sustainability in public education. After all, change is easier to achieve with the younger generation, whether by teaching or by example. They can also educate and sensitise their own families to global environmental issues. Initially, environmental education was included in classroom teaching, ethics and environmental studies in primary school, but now it is also included in the framework of several subjects (NAT, 2012). The current National Curriculum of 2020 (NAT, 2020) includes environmental protection and sustainability, but it still plays a minor role. The situation is better in biology, geography, ethics and science (grades 5-6). It is striking that the subjects concerned are still predominantly science, while mathematics and real sciences are not mentioned in the NAT. Moreover, it is also apparent that chemistry and physics are not given a prominent place in the context of dealing with environmental problems. In physics, environmental sustainability is most prominent in the relationship between energy and the environment in 8th grade, followed by a 12-hour block on the preservation of the integrity of our environment at the end of 10th grade, which includes noise pollution, the role of the ozone hole in our daily lives, the greenhouse effect and alternative, green energy production.

Environmental education is present in physics education but is not given a prominent role. Often the problem is the reduced number of lessons. But we have to admit that even with this, there is still a lot of potential for environmental education for students, as it does not have to be seen as a separate subject. In many cases, assignments and projects can be given to students on this topic that can be adapted to the specific subject area in the curriculum.

The key to assigning tasks and projects is to adapt them to the age and knowledge of the students. That's why we thought that the most effective way to tackle global problems was to tackle them in line with students' development. At the beginning, the younger age group will only be introduced to problems related to their own environment, but over time, by grades 10-11, they will have grown up to learn about global problems. Micro-scale is understood to mean those phenomena that can be observed and measured in the students' immediate environment, i.e. that allow direct measurements, so it takes part from 7th grade to 9th grade students teaching. The meso-scale is slightly broader, covering a wider environment, allowing the search for urban and regional problems and solutions. At the meso-scale, it is no longer necessarily expected that measurements can be made, but rather that research and data collection can be carried out on topics about which students are likely to have some knowledge. For example, the majority of students have some knowledge of the country's energy production, of large power plants, and this knowledge is expanded and refuted by acquiring scientific knowledge. This can be use on 9th and 10th grade. In older ages we can use macro-scale studies. The macro-scale part of the task involves complex systems about which they have little knowledge as a whole, so the task for this domain is already concerned with analysing more extensive data. It can be seen that these scales not only involve spatial growth, but also the complexity of the tasks, thus tracking students' skill development.

5. Project ideas for physics lessons

The following are some of the projects and project ideas underway. We will then discuss their links to the National Curriculum.

In grades 7-8: "*In line with the age phase, the processing of the curriculum is phenomenon-oriented, i.e. it is based on some tangible, observable, experienceable phenomenon. The choice of topics is practice-oriented and the aim of each topic is always to acquire practical knowledge that is useful in everyday life*." (NAT, 2020). In line with this, students learn about environmental problems in their own local environment through measurements and experiments.

Grades 9-10: "*The aim is to strike a balance between problem-focused, practical and knowledge-based learning in order to maintain motivation and to enable all students to learn effectively, creating the opportunity for students to become logical thinkers, adults who understand the interconnectedness of the world and are ready to make responsible choices*." (NAT, 2020). In grade 9, they deal mostly with meso-scale environmental problems, and then, broadening this, they move on to some global problems in grade 10.

In grade 11: Physics is only optional, where the primary aim is to prepare for advanced level and further education. At this point, the aim is typically to understand more complex problems, so environmental problems pop up from time to time. In Hungary, the exam from any kind of science is not obligatory, but students can choose it as a final exam's subject. In Hungarian education system, students choose subjects in their 10th grade, from which they will learn on an advanced level and they would like to take advanced final exam. For those who do not take science as an optional subject, the 2020 NAT will provide complex science at this level. The aim of this subject is to familiarise students with environmental problems and human responsibility in their development. The main title of the subject is Man and the Environment, within the following major units headings appear: *"Get to know the nature"; "Human activity in shaping the environment"; "Raw materials, energy sources"; "Changing climate"; "Biodiversity"; "Environment and health"; "Our cosmic environment"* and *"Visions for the future"* (NAT 2020, A-level physics exam assessments (2020)).

In the next section, we will present some of the projects that the students have done in physics class, which are age-appropriate and in any case develop competences related to research, engineering and precision measurements. The projects are open-ended in their initiation and design, as described in the 2020th American Institute of Physics Conference publication of Vörös (Vörös, 2020), so teacher reflection and academic supplementation are important parts of the project in addition to student reflections.

5.1. Example projects

Gread 7 - Measurement

The introduction to science starts with units of measurement. In physics, this means the SI system of units. So we are also introduced to temperature as a quantity. The following exercise is a good opportunity to learn about the specificity of the age group and to introduce a scientific, experimental approach. It could be a classroom measurement if the school's local conditions are suitable (there is a busy road and a large wooded park). But it could also be given as homework / homework assignment. As a homework assignment it is set for groups of two.

Task assignment: one member of the pair should take temperatures at the busy concrete road and the other at the wooded area, twice a day, at the same time, for a week. (The map of the measurement can be seen on the Figure 2.) The pairs should make a separate diagram of the measurements and evaluate the results. What similarities and differences can be observed? What could cause any differences?

Advice for the measurement: as the measurement was carried out in early autumn, the sun is already up when you arrive at school in the morning, so it is a good idea to take one measurement then and the other after school.

The aim of the project is to give students an idea of the environmental impact that the lack of green spaces can have on our daily lives. It also shows that urban sprawl and car traffic increase temperatures locally.

Experience: the difference between built-up and green areas can be measured with a simple shaded liquid thermometer. The measurement is not burdensome, takes little time and the students spent on average half an hour analysing the data. Discussing the measured results took between half an hour and an hour, depending on whether the students had included global warming in their lesson. In the discussion, it was important to focus on the preservation of green spaces. If the group brings up car traffic as a factor, then public transport can also be targeted to reduce local temperatures.

The results of the measurements were basically shocking to the students, mainly because in autumn the difference of a few degrees is not as noticeable as in the summer heat, but several of them noted that the temperature difference between green and built-up areas is already noticeable in summer. The measurement took place between 7th and 11th of November 2022. The Figure 1. also shows the daily warming and the difference between the temperatures in the wooded (City Park Sunbathing Area – Városligeti Napozórét) and the built-up, busy (East Railway Station – Keleti Pályaudvar) areas.

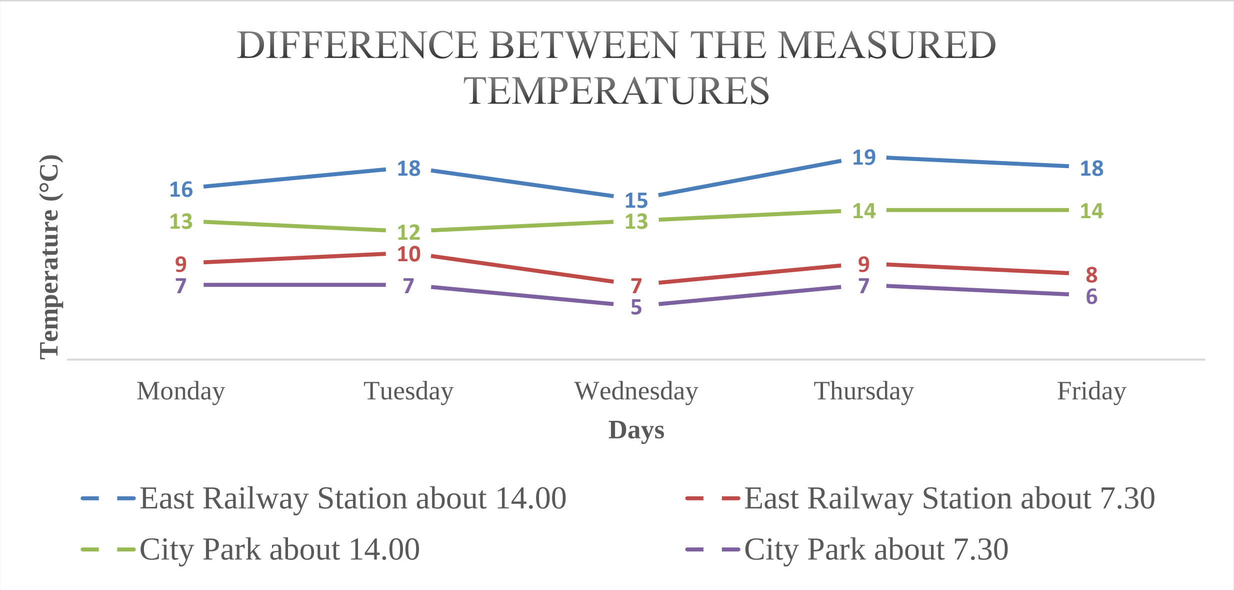

Figure 1.: Chart showing students' measurement results

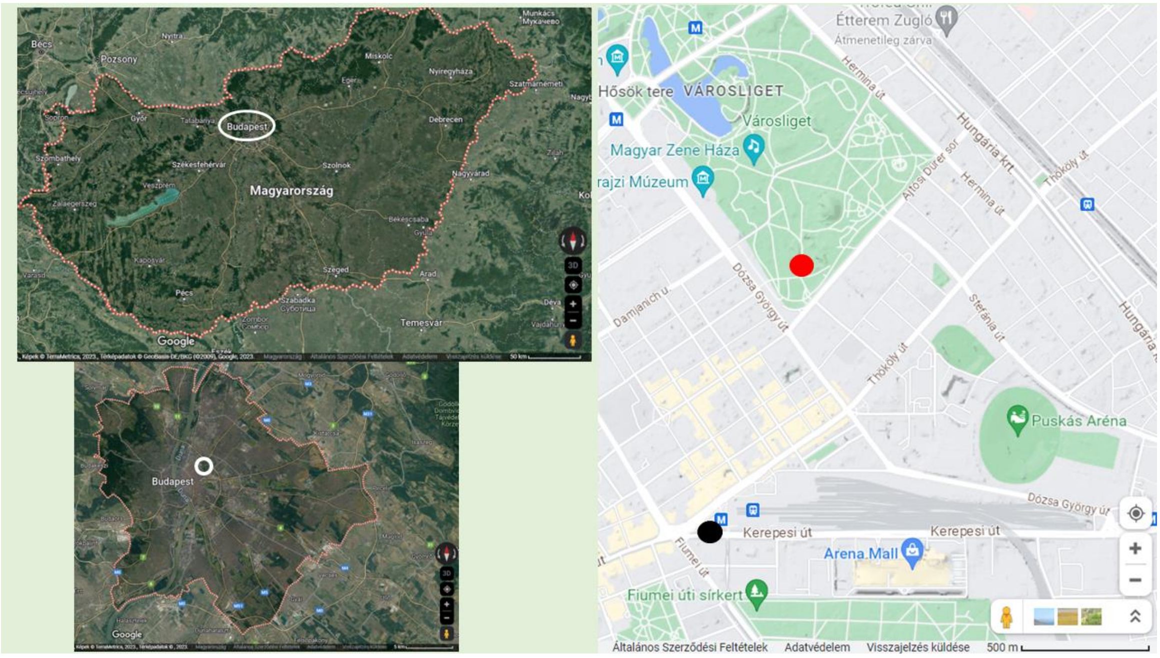

Figure 2.: Top Left: The map of Hungary; Bottom Left: The map of Budapest; The white circles point the zooming part of the map; Right: The map of school area, red dot: Central Park, black dot: East Railway Station; These maps were made by Google Maps

<u>Grade 8 – Example for calculation</u>

With a better foundation in mathematics, they are expected to be able to solve simple equations, so it is really from 8th grade that they are expected to solve numerical examples.

How long does it take for the dust from the volcano in Iceland to reach us? Assume that the dust spreads uniformly at a speed of 108 km/h (Richards-Thomas and McKenna-Neuman, 2020). The distance between the volcano and Budapest is about 3000 km.

The calculus example is not particularly more difficult than the general examples we solve in class. It is also advantageous because its longer wording will help you prepare for the later mathematics and physics exams, which also have a longer wording. Solving the problem did not cause any problems for the students and allowed room for discussion. We discussed why it is difficult to make such forecasts and what makes the work of meteorologists difficult. Simplifications can be a big focus at the beginning of physics studies, since we are basically talking about mass point kinematics and also mass point dynamics. We solve a lot of examples in these subjects where models and neglect are important, so they didn't encounter modelling in this exercise, so they were not particularly bothered by these approximations. The results can also be compared with real data, which shows that the models do help to describe reality The

2018 volcanic eruption resulted in the closure of Europe's entire airspace due to the dust plume, while smaller eruptions do not allow dust to reach the country's airspace, e.g. the 2011 eruption dust plume did not reach us (Eyjafjallajökull, 2010; ESA: Satellites monitor Icelandic ash plume, 2011)

Grade 9 - Think about it!

At this stage, it is possible to give slightly more complex tasks, as students have more advanced abstraction skills and two years of science knowledge. So, we dare to dive into thermodynamics, especially calorimetry and thermal expansion.

The media often claim that melting icebergs are causing ocean levels to rise. If a 1000 m^3 iceberg that has been floating on the water melts, how much will the water level rise? In our case, could it mean that melting ice alone is causing the rise in water levels? Think, what else could be causing it? Do the math! Try it on your own first, if you really can't do it, check out the help in the QR code below.

Figure 3.: QR code linked to the help

The experience of the exercise is that in the counting part of the exercise, students omit the change in volume between ice and water from the count. The completion of the counting task is also not part of the base examples, so they had to think a bit to calculate the increase in water level due to the melting of ice. And from the many data sets on the internet, not everyone found the same data on water level rise, but it became clear to everyone that it was not just melting ice that was causing the water level rise. 3 out of 18 students cleverly thought that melting land ice could have a more significant effect on water level rise than melting floating ice. Of course, we discussed, that the ice sheet floating on water has no effect to the see level, even when they melt. Finally, we also used data from the Greendex (Csaba, 2021) site to see how much sea level rise there has been in the last 50 years, and what proportion of this could have been due to rising temperatures.

Grade 10 - Look it up, write an essay.

We now give students a much freer rein. The task is less bounded than before and requires research. Its relevance for this age group is that someone who is not interested in physics may be interested in this everyday topic, which also shows how our everyday choices can influence global processes. The following complex task is inspired by the 16th assessment of the A-level physics exam (A-level physics exam assessments, 2020).

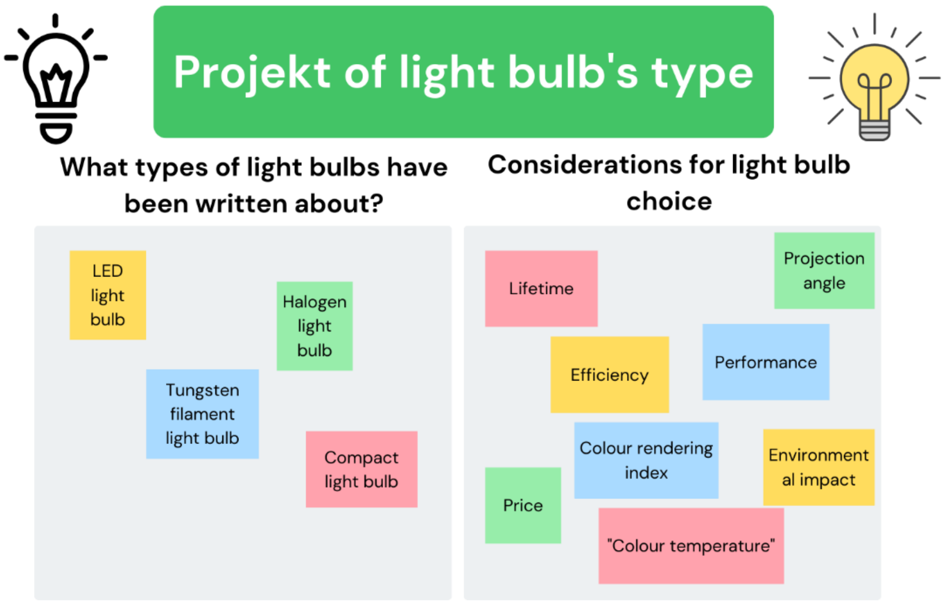

Figure 4. Summary of the light bulb project

Find out which light bulb to use in which room! Think about what might influence this? (E.g.: How often do we turn on the light?) We often hear how much energy and money we save by using an energy-saving light bulb (Kelly 2016; Obi, 2016; Lumenet, 2023,). If everyone used energy-saving light bulbs, how much energy would be saved? Write down the approximations you use and the order of magnitude of the energy thus obtained (e.g. household energy, city energy, power plant energy). Do we really save energy in all cases with energy-saving bulbs? Draw up a summary of the different types of light bulbs on the market based on the previous questions and include: Which room should I use it in? How much energy can it save per year? How much money does it cost? The expected length is at least one A4 page.

The calculations show that the energy-saving light bulb is actually better value for money than the conventional bulb. To do this, they needed to know their lifetime comparison, efficiency and wattage, which they had researched themselves. It can be seen from the submissions that they looked at the four major types of light bulbs (Figure 4.) in general and examined at least 4 or 5 different aspects of which bulb is best for which room.

The decision can be influenced by a number of factors, as mentioned earlier.

Some examples of practicality. There are some areas where there are local light sources where there is a need for local lighting. More uniform lighting is needed in classrooms or workplaces. In the street, you need diffused light and, to minimise light pollution, you need lamps that throw little light into the sky. In the theatre, coherent, parallel, focused but bright spotlights are used. In the cinema, they aim to light only the screen. Vehicles must be clearly visible, so small but powerful light sources are used.

Incandescent lamps are not economical at all, because they produce 95% heat and only 5% light. Fluorescent lamps are more economical, but the light from conventional fluorescent lamps flickers quickly, which is not healthy. The compact (energy-saving) lamp is cheap to run, but it should only be used where it is left on for long periods of time because it is slow to reach full brightness. LED bulbs are pleasant and economical, but are more expensive than other options today. It is clear that the choice of light sources requires careful consideration.

What is the best choice depends on where you put it:

- If the operating time is low (e.g. toilet, pantry), a halogen bulb is the best because it is the cheapest. And the higher consumption is less of a problem, as it lights up less.
- If the operating time is higher (e.g. living room), a compact fluorescent or LED is recommended.
- In a room where the lamp is frequently switched on and off, a compact fluorescent lamp is not recommended because it will break down quickly. Halogen or LED lamps are recommended.
- If the light source is to be placed in a reading lamp, a halogen bulb or LED is also recommended. Not that there is anything wrong with the light from a compact fluorescent tube. It doesn't flicker, it gives a steady, excellent light. The problem is that it emits a lot of electromagnetic radiation within about half a metre.
- Pay attention to the colour temperature! For daylight, choose a warm (yellowish) light for the bedroom. Warm light improves comfort and helps you relax. Cold light is not suitable for living rooms. The situation is different in the kitchen and bathroom. Here, cold (white) light is more suitable, it increases the feeling of cleanliness. On the product box you will find a three-digit number, which is the colour code. The warmest light is

825. 825, 827 and 830 are for living rooms, 835 and 840 for kitchens and bathrooms. 865 is a cold light and should never be taken home.

This project also showed that they could be expected to analyse a wide range of data. For example: i) using and analysing data from the Hungarian Meteorological Service (HMS, in Hungarian OMSZ), or ii) extracting some regularity from data from other large databases.

Brightness is also important from another point of view, namely the radiation from the sun. Let's look at another example activity that deals with the relationship between light intensity and the amount of air pollutants.

An example activity: Use your phone to measure the light intensity (example apps: Physics Toolbox, Hukseflux Pyranometer) at least three times every day (for a week). Make sure that the measurements are taken in the open air, preferably from the same angle and from the same angle of inclination of the phone. Try to spread the measurements over 3 parts of the day (morning, early afternoon, early evening - when the sun is still shining) and take them at about the same time on different days. Compare what you find interesting between the measurements taken at different times! Then find the nearest meteorological station that measures air quality where you live and try to find a relationship between the change in air composition and the change in light intensity (Lee et al. 2010; Zhang et al. 2020; Yang et. al., 2022; Air Quality, 2023). If you find a link, also look for how the change in the air component can be linked to human activity. If you cannot find a relationship between your own measurements and the data series, try to justify why! Record your measurements and conclusions in a report. The project was inspired by measurements in heavily polluted air in major Chinese cities (Yang et al., 2022) and Seoul (Lee et al., 2010), which showed that polluted air affects light intensity.

The new types of mobile phones all have a light intensity sensor, which allows the device to automatically set the right brightness level. That's why most mobile phones have the sensor on the front-facing camera, but it's worth checking which camera's data the device uses to measure light intensity before taking a measurement. The project required students to plan the measurement themselves, allocate their time and find the right data, so a high level of autonomy was needed to complete the task. They developed their research, analytical and mathematical skills, while looking for relationships between complex and diverse data. Although the task required a lot of discourse, it was useful to get an insight into the complex processes, instruments and measurements involved in air quality measurements. The use of mobile devices for measurements in the classroom is a motivating factor for students. There are several articles and websites that deal with the use of mobile devices in the classroom (FizziQ; Science and technology - Physics with Phones; Monteiro and Marti, 2022)

The children gave positive feedback on these activities, saying that they "took them out of physics lessons" and did not expect them to do the usual tasks. What is even more interesting is the feedback received for the grade 10 activity, where the student experienced that he "could do something about energy waste, something that did not involve a complete change of lifestyle". The 10th project, mentioned second, showed many interesting things, such as the difference in air quality between the city centre and the suburbs, although not all of them found a link between light intensity and air pollution. But there were very nice summary diagrams that we could compare and draw common conclusions. The following are the measurement results of one student (György Czvikovszky) (Figure 6.)

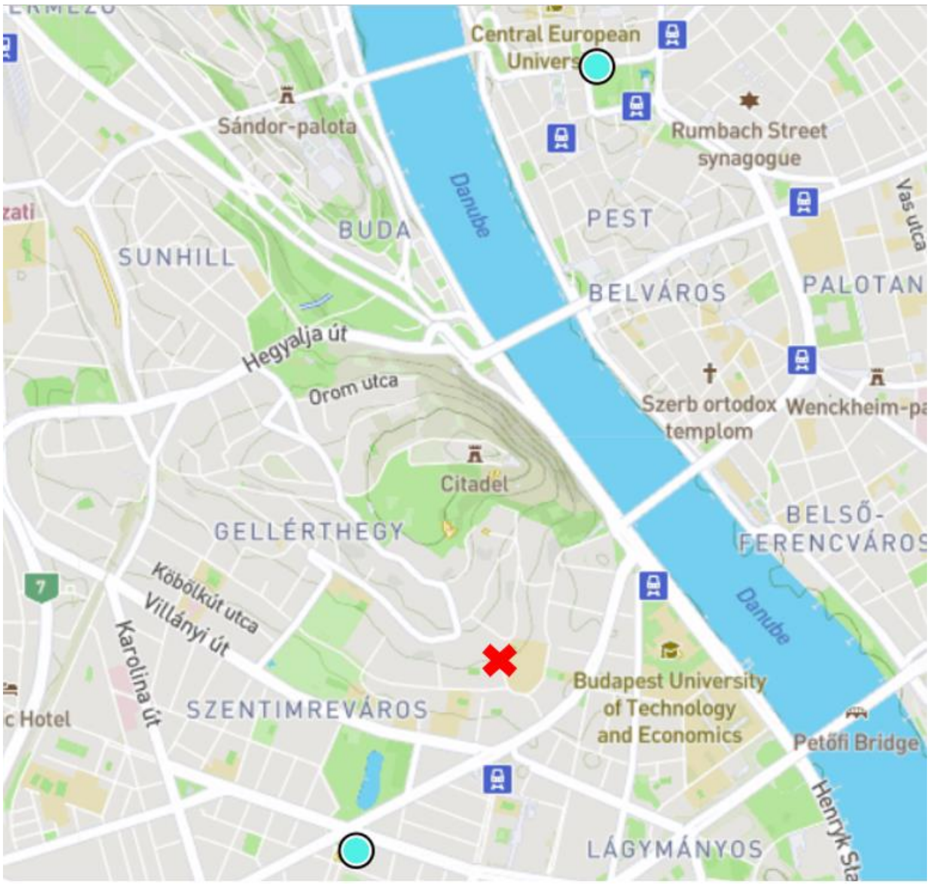

Figure 5. On the map of Budapest, turquoise dots indicate the air quality monitoring stations whose data were used for the project, red X indicates the measurement locations

(The map is from Hungarian air quality: https://legszennyezettseg.met.hu/levegominoseg)

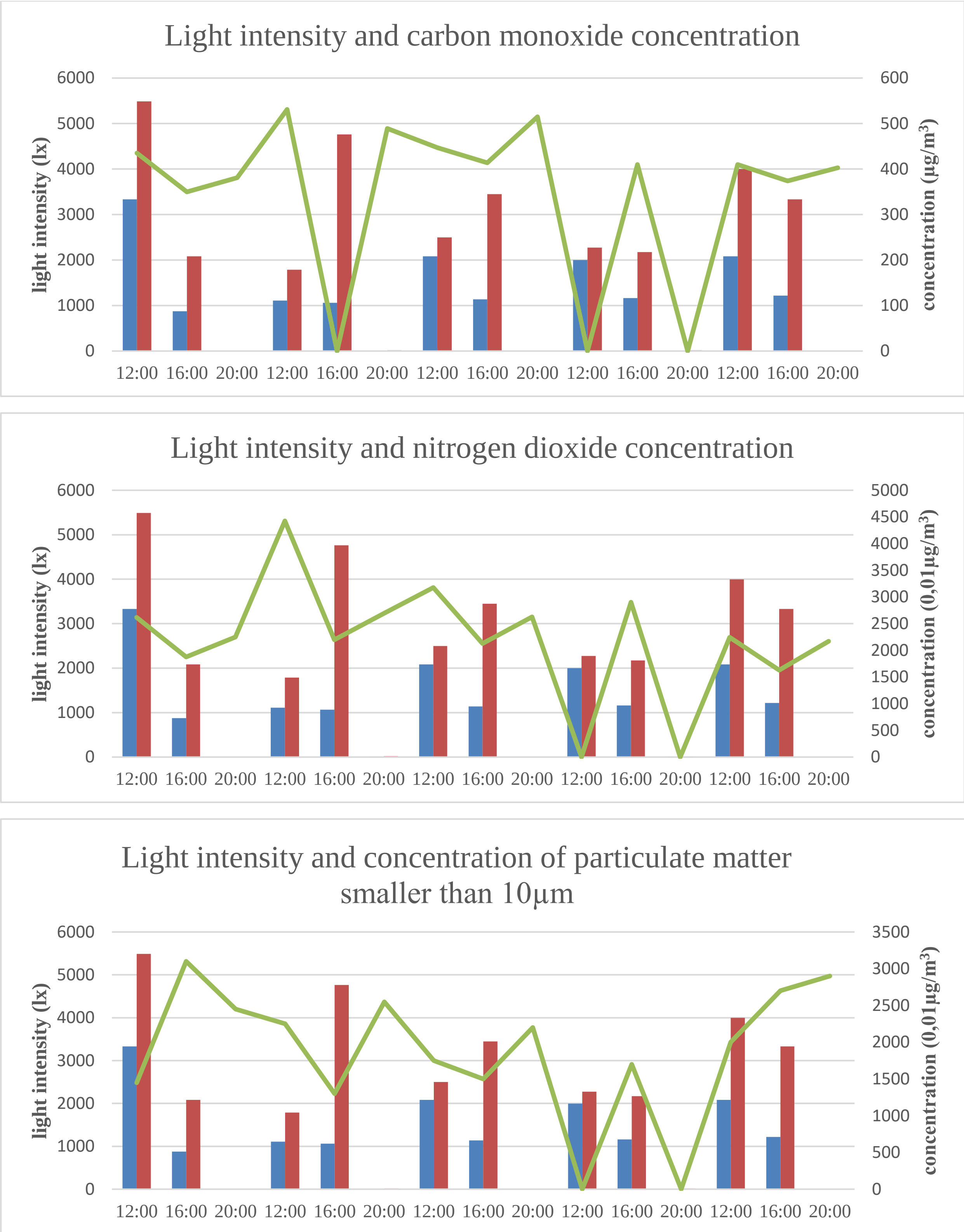

Figure 6. Diagrams made by the student from his own measurement results. Blue bar is A place of light meter, red bar is B place light meter, App: Physics Toolbox, green graph is the concentration of the substance

The measurements took place between 3 and 7 May 2022, using a telephone light intensity meter at two locations. Location A is an open wall window at a height of about 1 m from the ground, while location B is a garden table, also about 1 m from the ground in the same place (See Measurement location on the figure 5.). With this set-up, the light rays at both locations were perpendicular to the phone. At the measurement place, the sun was visible all the time during the measurement. The discrepancy between the results measured at the two locations is a measurement of the direct light rays and the light rays entering the room. During the measurement period, rain was only present in the afternoon of the first day, while clouds were typical at the measurement times. But the results of this day are not shown in the diagrams produced.

The air quality data were obtained by averaging the data from the two nearest stations to the measurement point (Figure 6.). There are 13 air quality monitoring stations in Budapest, and the National Meteorological Service provides data every 60 minutes (Air quality, 2023). The stations measure the presence of various substances that are most likely to characterise air pollution, such as carbon monoxide, nitrogen oxide, nitrogen dioxide, ground-level ozone, PM10[1], PM2.5[2], sulphur oxide and benzene. (Air quality, 2023)

We were also able to determine the air quality on a given day from the measuring stations. The following table will help you with this discussion (Figure 7.)

Concentration of pollutants $\left(\frac{\mu g}{m^3}\right)$						
	Good	Moderate	Unhealthy for sensitive groups	Unhealthy	Very unhealthy	Hazardous
Benzene	0 – 4	4 – 8	8 – 10	10 – 20	20 – 30	30 – 50
CO	0 – 4.000	4.000 - 8.000	8.000 – 10.000	10.000 – 20.000	20.000 – 30.000	30.000 – 50.000
$PM_{2,5}$	0 – 10	10 – 20	20 – 25	25 – 50	50 – 75	75 – 800

[1] Particles of dust that are less than 10 micrometres in diameter.
[2] Particles of dust that are less than 2.5 micrometres in diameter.

PM_{10}	0 – 20	20 – 40	40 – 50	50 – 100	100 – 150	150 – 1.200
NO_2	0 – 40	40 – 90	90 – 120	120 – 230	230 – 340	340 – 1.000
O_3	0 – 50	50 – 100	100 – 130	130 – 240	240 – 380	380 – 800
SO_2	0 – 100	100 – 200	200 – 350	350 – 500	500 – 750	750 – 1.250

Figure 6. Concentration of pollutants $\left(\frac{\mu g}{m^3}\right)$. Data came from the Hungarian National Meteorological Service (Országos Meteorológiai Szolgálat) (https://legszennyezettseg.met.hu/levegominoseg/informacio/aq-index-tajekoztato)

The student was only able to prognose a correlation with dust, i.e. the higher the dust concentration, the lower the light intensity.

The aim of the project is not primarily to find the actual, complex relationship between air pollutant particles and mobile measurable light intensity, but to think about what influences measurable light intensity. This was the main theme of the assessment discussion after the handing in of the protocols, to recognise the complexity of atmospheric processes. It was also emphasised that possible relationships that were discovered in the measurements could be due to other factors that had not been taken into account. This illustrates the difficulties of scientific understanding.

An important contribution of the project is to link optics with modern physics. The measurement is based on the logic of how light is scattered by polluting particles in the atmosphere. In this way, the physics of light scattering can be transferred from the similarities of the Rutherford experiment to atomic physics.

6. Final thoughts and assessments

Projects with students showed that student motivation increased significantly compared to the beginning of the project. However, as well as increasing their knowledge of physics, the older students were able to experience a system of scientific measurement and reasoning. The younger age groups were able to gain insights into the use of physics knowledge at its frontiers through guided experimentation and thematic exercises. Tasks thematically addressed regional and global natural problems, providing a good opportunity to develop natural awareness.

The projects are a good stimulus for reflection, but beyond their completion, it is important to support the teachers in their work, motivate students to complete the tasks and then evaluate them reflectively. The tasks are designed to provide a good opportunity for nature education and the development of naturalistic thinking. Depending on the context, they can be used to raise awareness of global environmental issues.

As a result of the projects, students could experience that built-up areas increase temperatures, gain a deeper insight into the understanding of sea level rise through a numerical example. They also explored the complexity of the spread of air pollution and did research by comparing light bulbs. And a discursive discussion of the projects gave space to environmental education from a scientific perspective. Projects are evaluated through formative evaluation, which is used to help, correct and reinforce during the process, and a final summative evaluation, which is a rating against the objectives set. The importance of this aspect of assessment is increasingly recognised in education and its use supports the overall workflow of student. (Nicol and Macfarlane-Dick, 2006; Theall and Franklin, 2010; Trumbull and Lash, 2013).

Acknowledgement: The data analysis was partly supported by the FAIR Network of micrometeorological measurements COST Action (CA20108).

References

Air quality (2023). (Ordinary title: Levegőminőség.) (2023, March 13). National Air Pollution Monitoring Network (In Hung.: Országos Légszennyezettségi Mérőhálózat) https://legszennyezettseg.met.hu/levegominoseg (last viewed 2023.05.10) (In Hung.)

A-level physics exam assessments (2020) Advanced physics graduation measurements; Based on 2020th National Core Curriculum (Ordinary title: Emelt fizika érettségi mérések; 2020-as NAT alapján) https://dload-oktatas.educatio.hu/erettsegi/nyilvanos_anyagok_2023tavasz/Fizika/fizika_emelt_szobeli_meresek_2023maj.pdf (last viewed 2023.05.10) (In Hung.)

Ballér, E. (2003). Some issues in the assessment of the 1995NAT (National Curriculum) (Ordinary title: Az 1995-ös NAT értékelésének néhány kérdése.); Iskolakultúra, 13(12), 3-18. (In Hung.)

Csaba, S. (2021). Sea-level rise. (Ordinary title: Tengerszint-emelkedés.) Greendex. https://greendex.hu/tengerszint-emelkedes/ (last viewed 2023.05.10) (In Hung.)

Csapó, B. (2005): Complex problem-solving in PISA 2003 (Ordinary title: A komplex problémamegoldás a PISA 2003 vizsgálatban) Új pedagógiai szemle 55. 3.sz. 43-52. (In Hung.)

Dodds, J. (2011). Eco-anxiety and defence. In: Dodds: Psychoanalysis and Ecology at the

Edge of Chaos. London: Routledge, 2011, 41-56. (Hungarian translation in IMAGO, 2019, 8(4), 37-54.

ESA: Satellites monitor Icelandic ash plume (2011). https://www.esa.int/Applications/Observing_the_Earth/Meteorological_missions/Meteosat/Satellites_monitor_Icelandic_ash_plume (last viewed 2023.05.10)

Eurydice: Hungary - especially the Second chapter: Levels of the Education System made by European Commission. https://eurydice.eacea.ec.europa.eu/national-education-systems/hungary/overview (last viewed 2023.11.02)

Eyjafjallajökull (2010). How an Icelandic volcano eruption closed European skies - NCAS. (2022, September 22). NCAS. https://ncas.ac.uk/eyjafjallajokull-2010-how-an-icelandic-volcano-eruption-closed-european-skies/ (last viewed 2023.05.10)

FizziQ – Your Smartphone is a Science Lab: 50 Physics Measures you can do with your mobile https://www.fizziq.org/en/post/turn-your-smartphone-into-a-scientific-instruments (last viewed 2023.08.18)

General Assembly of United Nations (2015). Transforming our world: the 2030 Agenda for Sustainable Development. A/RES/70/1: https://documents-dds-ny.un.org/doc/UNDOC/GEN/N15/291/89/PDF/N1529189.pdf?OpenElement (last viewed 2024.01.30)

Horvath, L. (2010) Nitrogen in the environment (Ordinary title: Nitrogén a környezetben). Élet és Tudomány, 2010/6, 172-174 (In Hung.).

Hukseflux, Pyranometer App: https://www.hukseflux.com/products/solar-radiation-sensors/pyranometers/pyranometer-app (last viewed 2023.08.10)

Hungarian Meteorological Service, Meteorological Database https://odp.met.hu/ (last viewed 2023.11.02)

Lenches, Ch. E. (1998). Environmental education in Hungary: Constraints and limitations; Graduate Student Theses, Dissertations, & Professional Papers. 7845. https://scholarworks.umt.edu/etd/7845

Kajner, P., Lányi, A., Takács-Sánta, A. (2013). Good examples of the transition towards sustainability in Hungary. (Ordinary title: A fenntarthatóság felé való átmenet jó példái Magyarországon.) Nemzeti Fenntartható Fejlődési Tanács. NFFT Műhelytanulmányok – No.18, 278 p. (In Hung.)

Kelly, K. (2016). A different type of lighting research - A qualitative methodology:. Lighting Research and Technology. 49. 10.1177/1477153516659901. https://www.researchgate.net/publication/305746297_A_different_type_of_lighting_research_-_A_qualitative_methodology (last viewed 2023.05.10)

Kováts-Németh, M. (2011). The need to educate for sustainability (Ordinary title: A fenntarthatóságra nevelés szükségessége). Magyar Tudomány, 2011.10 http://www.matud.iif.hu/2011/10/03.htm (last viewed 2024.01.31)

Kováts-Németh, M. and Földes-Leskó, G. (2019). Knowledge widening and attitude improvement by Forest Pedagogy. Journal of Applied Technical and Educational Sciences, 9(3), 4-30. ISSN 2560-5429; http://doi.org/10.24368/jates.v9i3.134_2

Kónya, Gy. (2018) Environmental education contents in textbooks and output regulators for high school education. Journal of Applied Technical and Educational Sciences, 8(1), 36-51. ISSN 2560-5429; http://doi.org/10.24368/jates.v8i1.22

KSH Environment Picture (2018). (Ordinary title: KSH Környezetkép 2018) https://www.ksh.hu/docs/hun/xftp/idoszaki/pdf/kornyhelyzetkep18.pdf (last viewed 2023.05.10) (In Hung.)

Lee, S.-B., Bae, G.-N., Lee, Y.-M., Moon, K.-C., Choi, M. (2010). Correlation between Light Intensity and Ozone Formation for Photochemical Smog in Urban Air of Seoul. Aerosol and Air Quality Research, 10, 540-549. https://doi.org/10.4209/aaqr.2010.05.0036

Lehoczky, J. (1999). School in nature, or Environmental education is practice (Ordinary title: Iskola a természetben avagy A környezeti nevelés gyakorlata) Raabe Klett Könyvkiadó. Budapest. page:100-123 (In Hung.)

Lumenet (2023). Lumenet. https://lumenet.hu/otthon-vilagitas (last viewed: 2023.05.10) (In Hung.)

Marks, E., Hickman, C., Pihkala, P., Clayton, S., Lewandowski, E. R., Mayall, E. E.,Wray, B., Mellor, C., van Susteren, L. (2021). Young People's Voices on Climate Anxiety, Government Betrayal and Moral Injury: A Global Phenomenon. https://doi.org/10.2139/ssrn.3918955

Monteiro, M., and Martí, A. (2022). Mobile Devices and Sensors for Physics Teaching. 10.48550/arXiv.2206.12062.
https://www.researchgate.net/publication/361557358_Mobile_Devices_and_Sensors_for_Physics_Teaching (last viewed 2023.08.18)

Nagy, A. (2018): The Hungarian Education System and its School-Critical Responses. Journal of Educational Sciences, 37(1), 18-26., http://doi.org/10.35923/JES.2018.1.02

NAT (2012). National Core Curriculum 2012 (Ordinary title: Nemzeti alaptanterv 2012) https://ofi.oh.gov.hu/sites/default/files/attachments/mk_nat_20121.pdf (last viewed 2023.05.10) (In Hung.)

NAT (2020). National Core Curriculum 2020 (Ordinary title: Nemzeti alaptanterv 2020) https://magyarkozlony.hu/dokumentumok/3288b6548a740b9c8daf918a399a0bed1985db0f/letoltes (last viewed 2023.05.10) (In Hung.)

Nicol, D.J., Macfarlane-Dick, D. (2006). Formative assessment and self-regulated learning: a model and seven principles of good feedback practice; Studies in Higher Education 31(2): 2-19.

Obi (2016). Energy saving light bulbs (Ordinary title: Energiatakarékos izzók.) OBI.hu. https://www.obi.hu/otletek-tanacsok/living/lighting/energy-saving-lamp-advisor/ (last viewed: 2023.05.10) (In Hung.)

Physics Toolbox App: https://www.vieyrasoftware.net/physics-toolbox-sensor-suite (last viewed 2023.08.10)

Pólya Gy. (1969). The school of thought (Ordinary title: A gondolkodás iskolája.) Gondolat Kiadó. Budapest. I. volume 129-135., II. volume 15-36. (In Hung.)

Radnóti, K., and Adorjánné Farkas, M. (2013). The approach to science education in schools (Ordinary title: Az iskolai természettudományos oktatás szemlélete) Iskolakultúra, 23(9), 49–62. (In Hung.)

Richards-Thomas, T., McKenna-Neuman, C. (2020). Laboratory Investigation of Particle-Scale Factors Affecting the Settling Velocity of Volcaniclastic Dust In: Journal of Geophysical Research: Atmosphere, 25(7), e2020JD032660. https://doi.org/10.1029/2020JD032660

Science and technology - Physics with Phones https://st.llnl.gov/sci-ed/Physics-with-Phones (last viewed 2023.08.18)

Sutton, M.A., Oenema, O., Erisman, J.W., Leip, A., van Grinsven, H., Winiwarter, W. (2011) Too much of a good thing. Nature, 472, 159-161. https://doi.org/10.1038/472159a

Theall, M., Franklin, J.L. (2010). Assessing Teaching Practices and Effectiveness for Formative Purposes; A Guide to Faculty Development; KJ Gillespie and DL Robertson (Eds); Jossey Bass: San Francisco, CA.

Trumbull, J., Lash, A. (2013). Understanding formative assessment: Insights from learning theory and measurement theory; San Francisco: WestEd. 20p. https://www2.wested.org/www-static/online_pubs/resource1307.pdf

Vörös, A. I. V. (2020) Outcomes of an Optional Environmental Physics Course in High School. AIP Conference Proceedings, 2218, 60008. http://fiztan.phd.elte.hu/letolt/outcomes.pdf

Westhoek H., Lesschen J. P., Leip A., Rood T., Wagner S., De Marco A., Murphy-Bokern D., Pallière C., Howard C. M., Oenema O., Sutton M. A. (2015) Nitrogen on the Table: The influence of food choices on nitrogen emissions and the European environment. (European Nitrogen Assessment Special Report on Nitrogen and Food.) Centre for Ecology & Hydrology, Edinburgh. UK. https://www.pbl.nl/sites/default/files/downloads/Nitrogen_on_the_Table_Report_WEB_1.pdf (last viewed 2023.08.10)

Yang, L., Gao, X., Li, Z., Jia, D. (2022). Quantitative effects of air pollution on regional daily global and diffuse solar radiation under clear sky conditions. Energy Reports, 8, 1935-1948. https://doi.org/10.1016/j.egyr.2021.12.081

Zhang, C., Shen, C., Yang, Q., Wei, S., Lv, G., Sun C. (2020). An investigation on the attenuation effect of air pollution on regional solar radiation. Renewable Energy, 161, 570-578. https://doi.org/10.1016/j.renene.2020.07.146

Short professional biography

Zsófia Nógrádi works as a teacher of mathematics and physics at the Radnóti Miklós Training School of Eötvös Loránd University (ELTE) in Budapest, and as a doctoral student at the Doctoral School of Physics Teaching of ELTE. Her research interests include the place and teaching of global environmental processes in secondary school physics education. She also completed her undergraduate studies at ELTE in Mathematics and Physics with a specialization in Mathematics and Physics and a bachelor's degree in Computer Science Physics.

Tamás Weidinger received his M.Sc. and PhD degrees in Meteorology in 1983 and 1992, respectively. He has been working at the Department of Meteorology Institute of Geography and Earth Sciences Eötvös Loránd University from 1983 up to date, and from 2013 as a habilitate associate professor. He participates in the Doctoral School of Physics, Teaching Physics Programme as supervisor. His main areas of education are general meteorology, micrometeorology, and dynamic meteorology. His main field of research is boundary-layer meteorology.

