Outcomes of an Optional Environmental Physics Course in High School

Alpár István Vita Vörös[1, a)]

[1] *Apáczai Csere János Highschool, 400074 Cluj-Napoca str. I.C. Bratianu nr. 26, Romania*
[a)]Corresponding author: vorosalpar@gmail.com

Abstract. In this paper I present a genuine approach of an optional science subject for students in 11th grade. In the last seven years I developed the curriculum for a one year Environmental physics course with one class per week. It discusses several topics regarding environmental flow in atmosphere and in the oceans, heat transfer and energy balance of the atmosphere, energy production, etc. A specific emphasis was taken on energy policies, with an inquiry-based approach and a role play on the future of energy production in Transylvania. The detailed curriculum of the environmental physics course is presented.
For the study of energy production a new method, the energy debate is presented. Results of a survey show significant difference between the attitude of students which followed the full energy debate activities and those who missed out the preparation discussions. Some misconceptions about the environmental impact of the energy sector are presented.
.

ROLE OF ENVIRONMENTAL EDUCATION

Many studies show [1] the importance of environmental knowledge. A lot of misconceptions [2] reside regarding environmental physics issues largely presented in mass-media, like pollution transport, environmental impact of different energy resources. Thus, it is important to make adequate learning situations and boost students' environmental attitudes and pro-environmental behaviour. Secondary school physics curricula in general deal with just a few environmental physics topics, but in the Romanian curriculum it is neglected completely. Thus I find of major importance in our system to introduce the teaching of environmental physics.

In 21st century schools, environmental (or sustainable development) education should be a priority at all levels and in all fields of education. Great Britain is at the forefront of environmental education, with the founding of the Environmental Education Organization and the Field Studies Council (FSC) in 1943, which has since 1945 established 17 educational centers in different parts of the United Kingdom (https://www.field-studies-council.org/about/briefhistory.aspx). The beginning of modern environmental dates back to the late 1960's and early 1970's. Nevertheless, comprehensive programs that affect the whole school system and affect a significant part of society have only been implemented in the last 20 years. Unfortunately, Romania is lagging behind in this and the culture of environmentally conscious behavior can only emerge from decades of informative work.

In 1977, at the UNESCO Intergovernmental Conference on Environmental Education in Tbilisi. The following recommendations were made [3]:

- it is necessary to modify the school curriculum, to prepare textbooks and materials for environmental education
- introduce modern educational methods, develop vocational training, teacher training and further training.

A first definition of environmental education was stated by William B. Stapp as: "environmental education is aimed at producing a citizenry that is knowledgeable concerning the biophysical environment and its associated problems, aware of how to help solve these problems, and motivated to work toward their solution" [4]. Physics teachers should take up this area of education, all the more as environmental physics is attractive to the student, promotes a deeper understanding of natural phenomena, and also contributes to the popularity of the subject.

Environmental education is also practical and children can learn things about how to reduce consumption or how to minimize environmental damage [5].

TEACHING ENVIRONMENTAL PHYSICS

I have used the experience and curriculum of some environmental education programs of the GLOBE program (https://www.globe.gov/), the energy project of Powers and DeWaters [6], the practical environmental projects CD-ROM [7] and debating as an educational method [8] to develop a new environmental physics course. Some ideas were taken from a Greek initiative as well [9]. The curriculum was developed for 11th grade students as an optional subject. We consider the study in the PISA measurements of students' attitudes towards science and their application in the following areas to be the guiding principle for the choice of curriculum and methods [10]:

To support student science research:

• accepting consideration of alternative viewpoints, thoughts and research
• supporting the consideration of real information and reasonable explanations
• logical and prudent conclusion making, expression of the need for creativity

Reinforcing our responsibility for natural resources and the environment:

• recognition of individual responsibility in environmental protection
• awareness of the personal, social and environmental consequences of one's activities
• willingness to take action to conserve nature's resources

Grade 11 was found to be the most appropriate for our optional course, as this age group already has the appropriate basic knowledge of science, and their ability to understand abstract and complex phenomena is well developed. We wanted to support the strengths of our students in our work, so we found it appropriate to use project teaching methods and inquiry-based methods.

The main goals of the Environmental physics course were: enriching physics education with new topics, boost student's environmental attitude, to form a pro-environmental behavior, to give an overview of the energy production sector.

HOW TO TEACH, PROJECT-ORIENTED TEACHING

Typically we use different forms of teamwork during my classes, both to develop the information needed for learning and to develop social competences. I use project-oriented education to mobilize students' inner creativity, and interested, talented students can research independently. Project-based learning (PBL) integrates knowing and doing. Students learn knowledge and elements of the core curriculum, but also apply what they know to solve authentic problems and produce results that matter [11]. The point is that both the topic and the elaboration of the topic come from the students. The criteria for project education in the literature are different, but we highlight the ones that we consider important in the Environmental Physics course:

1. The problem should be raised with the students.
2. The solution of the project should be connected to real situations and our local environment.
3. Give way to both individual and group work.
4. Develop it over a longer period of time.
5. Describe an interdisciplinary approach.
6. Teachers and students work together as equal partners with different competences.
7. The educator should retire to the stimulating, organizing, advisory function.
8. Relationships between students should be strong and communicative.
9. Conclude the project by presenting and evaluating the results (written and oral).

Since in many cases the methods we use do not have all of the features described above, I intentionally use the term project-based education, and in this case the project is based on specific research work, so we can also refer to Inquiry Based Learning IBL [12]. In our case, the projects were basically related to three topics: environmental

pollution, waste management and energy production. In most cases we tried to guide our students towards measuring tasks, which also required preliminary theoretical grounding in the given topics. In developing the topic, constant communication between the teacher and the students is needed to organize and develop the workflow. The method of debate, which in our case is particularly marked by the social dilemmas of energy production processes, plays an important role in the development of scientific thinking.

WHAT SHOULD WE TEACH? KEY CONCEPTS TO BE DEVELOPED

There are several concepts in environmental physics that usually cause confusion. Thus, it is important to properly clarify the causes of atmospheric flows, isobar lines, Coriolis force effects, weather and climate, as well as the concepts of heat quantity, heat exchange and temperature. At the same time, the differences between climate change and climate variability and the factors responsible for the greenhouse effect must be explained. In this section, the most difficult concept for students is the Coriolis force, which has been developed in some very useful textbooks for teachers in high schools [13,14]. Perhaps the most interesting of the videos is the visualization provided by the Massachusetts Institute of Technology (MIT) Faculty of Physics [15]. Using these materials students are able to explain atmospheric currents and the formation of Hadley cells.

In addition, a thorough and comprehensive understanding of the concept of energy, energy transitions and law of energy conservation is a priority. Regular acquaintance with the science of physics begins in our country in grade 6, but all students already have a preliminary knowledge of physical phenomena. They have in their minds child science, child physics, and this is definitely a factor to be taken into account. If we ignore it, the children keep their original ideas deeply learned and put the material to be learned at school in a "different layer" for use in school measurement.

What characterizes children's prior knowledge of energy? Before we learned about energy in physics lessons, most people refer to the term "energy" as referring to living beings (humans, animals) or machines. Some examples are: "an athlete needs a lot of energy", "we have energy when we eat chocolate". Fatigue is associated with running out, running out of energy: "I can't stand running out of energy." This point of view is supported by the use of the phrase who is active, busy, is "energetic", and when I am well rested, I am "full of energy". "Energy is something that we use to move most things." Students often believe that food-related energy (maybe what they learned in biology classes) is not accumulated energy, but is generated in our bodies when we eat food, and that when the materials are burned, energy is generated in the combustion process [16]. In other words, they are thought of as energy stored in food, in our bodies, or in carbon.

In the specific conception of the child, energy is "produced and consumed". They have no or little idea of energy storage, energy transitions, energy conservation. So they have to learn this.

The introduction of potential energies causes further confusion. In the case of hydroelectric power stations, energy production is difficult to imagine when a student sees the water of a collecting lake at rest. He does not see the inside of the power plant and, in the absence of movement, does not understand where the electricity comes from. Nowadays, it helps a lot to project a movie from the Internet for the students, so the operation of the hydroelectric power station can be demonstrated.

The correct acquisition and deepening of the above concepts is achieved by breaking down the curriculum according to Table 1.

TABLE 1. Environmental physics curriculum for 11th grade.

Topic serial number	Description of the topic	Number of classes
I. semester : Atmospheric phenomena and environmental pollution		**17**
1.	Characterization of the atmposphere	1
2.	Coriolis force. Atmospheric dynamics, weather fronts.	3
3.	Atmospheric optical phenomena.	1
4.	Atmospheric energy balance and the solar constant.	2
5.	Greenhouse gases.	1

6.	Environmental researches, causes and consequences of global warming	2
7.	Current environmental problems, flow of pollutants	1
8.	Presentation of gruop research projects.	4
9.	Ismétlés és tesztírás	2
II. semester: Climate change, ecological footprint and the energy production		**18**
10.	Viewing and discussing a documentary on environmental topics.	2
11.	Sustainable development and economy, analysis of consumer habits	3
12.	Electric bottle press practical activity.	1
13.	How big is my ecological footprint? – practical activity	3
14.	Possibilities for energy conversion. Energy sources (non-renewable energy sources, solar energy, wind energy, nuclear energy, hydropower, biomass, geothermal energy).	2
15.	Energy panel-debate	5
16.	Repetition and test writing	2
Total number of classes		**35**

During the first semester, students should be familiar with the major sources of pollution in our environment, their environmental impact, and be aware of ways to reduce pollution. Understanding these first requires introducing Coriolis force and discussing its atmospheric applications. Atmospheric dynamics, weather fronts, are deeply discussed with students. Calculating and measuring the atmospheric energy balance and the solar constant is an exciting task for students. To avoid pollution, one must know the process of contamination propagation, that is the atmospheric flow and their chaotic nature, which we use in computer simulations as well. Students develop group projects on the environmental impacts of humans. These projects lead to deeper understanding of concepts through exploration of our immediate environment and the joy of discovery through individual conclusions.

In the second semester, the main goals of a society based on sustainable development should be formulated with students. The first part is a change in consumer habits, in which I draw attention to overconsumption, the amount of food being littered, and the excessive use of packaging materials [17]. It is here that students are drawn to the new endeavour that has slowly begun to spread from the United Kingdom as a concept of circular economy [18, 19]. In this context, students look for examples of communities or companies that have already applied this concept. In the context of human influence on the environment, we introduce the concept of an ecological footprint. Applications available on the web allow you to calculate an individual's or family's ecological footprint. This allows students to compare their own ecological footprint with values calculated in different regions of the world and with the world average (www.carbonfootprint.com/calculator.aspx). Within the class, we compare the values calculated by each student and we identify the activity from which the differences originate. Modifying the data allows you to think about the most effective ways to reduce human impact on the environment.

In the field of energy, I first analyse the extent of energy consumption with the students, and then I turn to the question of energy production. The emphasis is on the energy transformation processes, which are realized by discussing the operation of individual power plants and the devices and appliances used in households. Here are some ideas for implementation:

I consider it important to analyse situations where we perform an activity with the illusion of caring for our environment. For example, a few years ago, every Cluj County high school received an electric bottle press to squeeze the plastic bottles discarded in the institution. In principle, removal becomes economically viable. The first problem is that a single bottle press cannot be used by hundreds of students at the school and has therefore not been put into operation. However, it was suitable for students to experiment with their lessons and make calculations about their effectiveness. Activity 12 of Table 14 was thus incorporated into the curriculum and became a student-friendly practical activity. According to the students' analysis, using a bottle press almost doubles our environmental load if we reduce the volume of plastic rubbish by simply mechanical pressing (by foot).

In the last major topic of the second semester, the energy panel-debate we discuss natural resources, especially energy sources [20]. In this section I use the energy panel discussion method. When conducting the panel discussion, I pay close attention to atomic energy, since in grade 11, this mode of energy production assumes many foreign concepts (radioactivity, atomic structure, nuclear fission, elementary particles) that are discussed briefly before students prepare for their individual role.

THE ENERGY PANEL-DEBATE

The energy debate, developed on the basis of the disputation program, consists of four different parts, with seven school lessons in total. One class is devoted to the introductory part (introduction to the panel-debate), three for the preparatory discussion (preparatory discussion, global view), two more to the actual debate (energy debate), and the last lesson to the discussion following the debate (discussion after the debate).

Introduction to panel-debate. In the introductory part, the teacher introduces the topic of the debate: students have to put themselves in a role-playing situation where, as a live TV show, a thematic panel discussion on the future of energy production in their region (in our case Transylvania) takes place. Putting themselves in the role of presenter, students can suggest several possible invited speakers: experts for different types of energy sources (solar, nuclear, wind, hydro, fossil fuels, geothermal, biomass and other renewable energy), environmental activists, politicians (mayor of our city, etc.), European Union energy policy expert or geologist.

Preparatory discussion, global view. Following the introductory phase, some major problems of the energy production sector are discussed: 1. The demand for energy is increasing as the population and the standard of living rises worldwide; 2. the need to reduce the cost of energy production through the use of technological innovation; 3. the depreciation of power plants over time, future investment and modernization; 4. reduce the environmental impact of energy production processes. In the next phase of the preparatory discussion, the energy production of different countries is examined by analysing the percentage distribution of different energy sources in the energy production of that country. According to these data a correspondence with the environmental load of the energy production sector is made (Figure 1). By analysing this data, students will gain a better understanding of energy production processes and their environmental impacts. The final issue of this part is the local energy production, which can be analysed by detailed, up-to-date information on the Romanian National Energy Agency website (www.sistemulenergetic.ro), a valuable and reliable source of information.

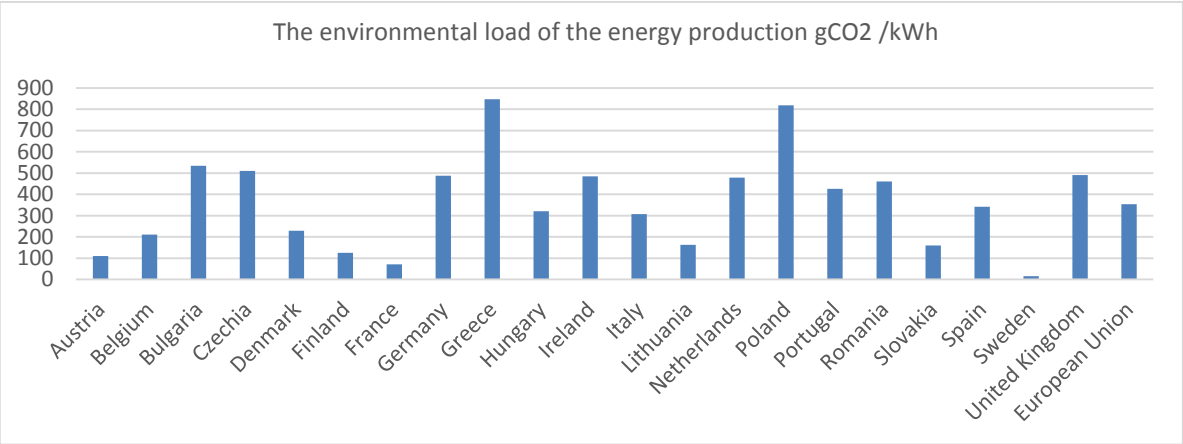

Figure 1. The CO2 emissions due to the energy production sector in EU countries in 2011. (*Data source: https://www.eea.europa.eu/data-and-maps/indicators/ overview-of-the-electricity-production-2/assessment-4*).

The energy debate. The activity is included in a double teaching class (2 x 50 minutes). Usually organized without a brake as students are so motivated by the topic and the extraordinary teaching method. The main role is played by the moderator of the debate, also played by a student. He will begin with a short keynote speech presenting the topic of the debate and some general information on the need for a new energy strategy for the region. In the first round, the moderator will give the floor to experts in various energy sources, presenting the principles, benefits and environmental impacts of different power plants. After presentations by individual experts, it is possible for environmental activists to express their views. In this first round, students in the role of politicians can also ask questions of experts to gather information and to take a scientifically sound position for future decision making. In the second round of discussion, the European Union energy policy expert will present the European Union's energy policy.

This will be followed by a presentation by a geologist about the region's currently untapped energy sources. Finally, politicians present their policies on the energy sector. Following their statements, energy experts and environmental activists can submit further suggestions or criticisms of the positions presented. To conclude the discussion, the moderator summarizes the main conclusions of the debate, proposing proposals for energy policy in the region based on the expert debate.

Discussion after the debate. The activity is evaluated in a single lesson. This is where the students, as observers, come to the fore, highlighting the main elements of the debate, its strengths and weaknesses, and possible material errors. In general, they can be very critical of their peers, but they also point out that a lot of new information has been gathered through this activity. In many cases, students report that their attitudes towards particular energy sources have changed dramatically. Generally, they have misconceptions about renewable energy, so that the term "green energy" is misleading to them. An important part of the whole activity is that the teacher must have a high level of confidence in the students and should not intervene in the comments as much as possible

EVALUATION OF THE PANEL-DEBATE METHOD

During the last five years (2014-2019), at the end of the activities, a survey was conducted on the change in student attitudes towards energy production as a result of the energy debate. Each year, one class participated in this activity. It should be noted that during the said 5 year period only four activities followed the exact methodology of the energy debate method, whereas in 2015 the activity was organized without the second part, "preparatory discussion, a global view". In this case, students were not given guidance, had to collect information individually, and did not receive suggestions for bibliographic resources. After each debate, I conducted a survey of students' perceptions, asking what percentage of energy production would be acceptable to our region in the future (2040).

Figure 2. shows the actual energy production mix according to data from 2016 compared with the opinion of students from classes with the full energy-debate method.

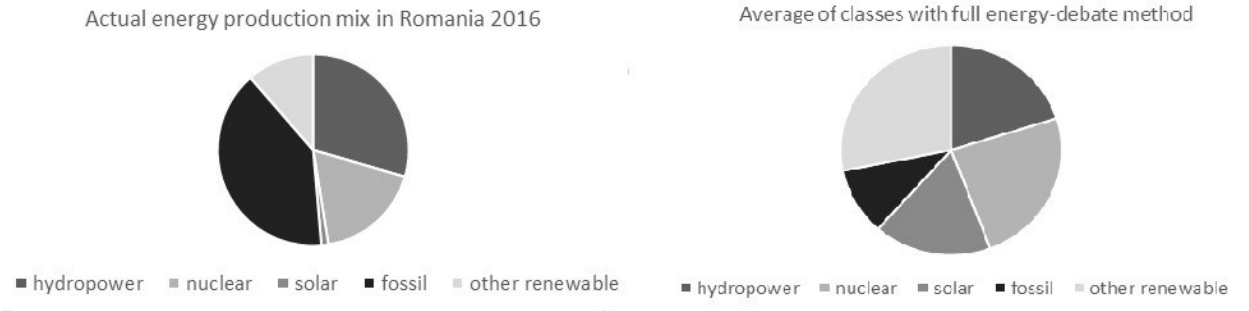

Figure 2. Energy production mix in Romania in year 2016 from data of the www.sistemulenergetic.ro site (left) and the opinion of students who had the whole energy-debate method applied (right).

The energy debate activity from 2015 served as a control group to examine how students can process information and data on energy sources and energy production without preparation and guidance. Already during the debate it was noticeable that the arguments of the actors were weaker, there were more material errors and incorrect statements. However, as shown in Figure 3, after the energy debate, the students' attitudes showed the same misunderstandings as those of young people who did not participate in the energy debate [21]. This control group estimates that in a relatively short period of time other renewable resources could have a 45% share of total energy production, while solar could achieve a 15% share. These "green energy sources" would largely replace nuclear (10%) and fossil fuels (7%), which these students strongly reject. The greatest difference is in the acceptance of nuclear energy: each of the other groups would agree to an increase in the share of nuclear energy (as shown in Figure 2.), whereas this group would rather reduce its share.

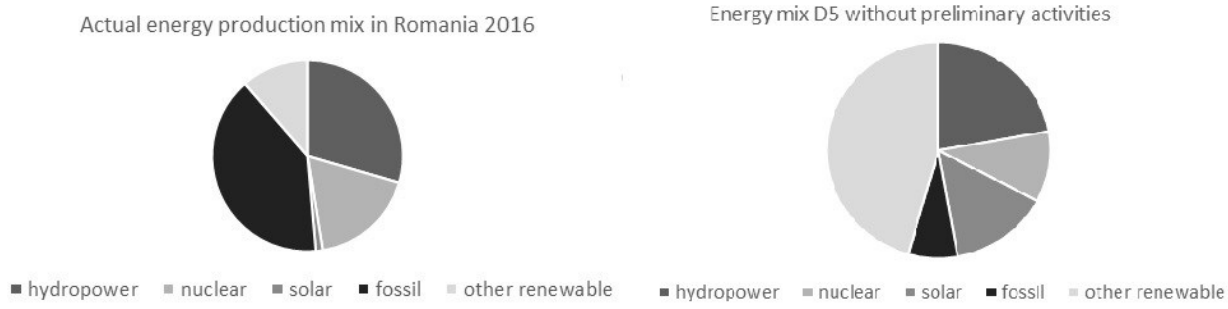

Figure 2. Energy production mix in Romania in year 2016 from data of the www.sistemulenergetic.ro site (left) and the opinion of students from the control group (D5 in 2015) with the preparatory discussion missing from the energy-debate method (right).

CONCLUSIONS

This paper presents the curriculum for Environmental Physics, developed in 35 lessons, for 11th grade students, which we developed in the current form over the past ten years. The subject covers atmospheric phenomena (Coriolis effect, Hadley cells, cold and warm fronts, optical phenomena in the atmosphere), environmental pollution, ecological footprint, solar constant, types of energy sources, analysis of energy consumption and energy production. Through this course we broaden the topics of physics teaching with cross-cutting topics in which students need to apply the different chapters of physics simultaneously, we promote the development of students' environmentally conscious attitudes and we raise awareness of the environmental impacts of energy production. During the course, we focus on project-based education and research-based learning (IBL), where students can get to know the above topics and introduce them to their peers.

The efficiency of a new method is presented: the energy panel-debate. We have explored the impact of energy debate as a new method on students' attitudes. Research with five groups of students demonstrates the importance of the discussion and preparation phase of this activity, as it helps students to better understand power generation systems and resolve predetermined misconceptions. Based on the experience of the energy debates of recent years, it can be stated that students do not have sufficient knowledge about energy sources, energy conversion and the production of electricity, and there are several misconceptions.

ACKNOWLEDGMENTS

This research was funded by the Content Pedagogy Research Program of the Hungarian Academy of Sciences.

REFERENCES

[1] A. Uitto, K. Juuti, J. Lavonen, R. Byman, V. Meisalo, *Environmental Education Research,* **17** (2), 167-186 (2011).
[2] J. E. DeLaughter, S. Stein, C. A. Stein, K.R. Bain, *EOS*, **79** (36), 429-436 (1998).
[3] UNESCO (1978) Intergovernmental Conference on Environmental Education, Final Report, *UNESCO-UNEP, Tbilisi*
[4] Stapp, W.B., *Environmental Education*. **1** (1), 30–31 (1969).
[5] Bennett, B.D., *Evaluating Environmental Education in Schools, A practical guide for teachers*, UNESCO Division of Science, Technical and Environmental Education, pag. 71-82. (1984).
[6] Powers, S.E.; DeWaters, J.E. Energy Systems and Solutions, *TeachEngineering Digital Library* (2009) *https://www.teachengineering.org/curricularunits/view/cla_energyunit*
[7] Practical Environmental Projects (1999) *CD-ROM* by Volvo

[8] Scherz Huryn, J.; *Teaching Sociology*, 14 (4), 266-269 (1986).
[9] Scoullos M., Malotidi V.; Handbook on methods used in Environmental Education and Education for Sustainable Development, *MIO-ECSDE*, Athens (2004)
[10] PISA 2006 Technical Report, OECD Programme for International Student Assesment, *https://www.oecd.org/pisa/data/42025182.pdf*, 327-344 (2009)
[11] Markham, T.; *Teacher Librarian*, **39** (2), 38-42 (2011).
[12] Schwab, J.; Inquiry, the Science Teacher, and the Educator. *The School Review © 1960*, The University of Chicago Press (1960).
[13] Gróf, A.; *TPI-15 Conference Proceedings*, Budapest, 119−124 (2016).
[14] Szeidemann Á., Gróf A., Tél T. A guided tour from the motion on carousels to cyclones and the Gulf Stream, full of surprises *http://theorphys.elte.hu/fiztan/Coriolis*
[15] *https://www.youtube.com/watch?V=dt_XJp77-mk*
[16] Frankowicz, M.; Maciejowska, I.; Martinas, K.; Radnóti, K.; Rimai, A. Energy in school textbooks: a comparative study. *Gamtamokslinis Ugdymas = Natural Science Education.* **1**, 2(23), pag. 34-41 (2008)
[17] Hailes, J.; The New Green Consumer Guide. You can Make a Difference, *Simon & Schuster Ltd. UK*, London (2007)
[18] Webster, K.; Rethink, Refuse Reduce… Education for sustainability in a changing world, *Field Studies Council Preston Montford*, Schrewsbury (2004)
[19] Webster, K.; Johnson, C.; Sense and Sustainability, Educating for a circular economy, *Ellen Macarthur Foundation*, e-book from *www.ellenmacarthurfoundation.org* (2010)
[20] Patterson, W.; Rebuilding Romania. Energy, Efficiency and the Economic Transition, *The Royal Institute of International Affairs, Earthscan Publications Ltd*., London (1994)
[21] Leitner, L.; Gondolom, hogy tudom, I think I know, *Gradus*, **5** (2), 292-297 (2018)