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ARTICLE

Panel debate on energy production in high school physics teaching[1]

Alpár István Vita Vörös

Abstract: This paper presents a method to develop students' knowledge about energy resources and energy production through scientific argumentation in a panel debate. The method was used with fifteen different 11th grade classes in a high school in Romania. In the last five years, research was conducted on the change in attitudes of students towards different types of energy resources and how they accepted environmental hazards resulting from energy production. Throughout these years, several misconceptions were observed regarding the origin of energy resources, the energy production processes, and their effects on the environment. To have a sound understanding of these misconceptions, a study was conducted with the help of a 21-item multiple-choice energy resources knowledge assessment. The test was completed by 720 high school students (9th to 11th grade) from nine different schools in Transylvania, Romania. Data analysis shows that misunderstandings regarding energy resources and energy production were similar to those in US schools and presented in other research papers. To help create a society well-prepared to make decisions about energy production constraints, it is essential that we add a chapter to the Physics curriculum. In this paper, we present our arguments for introducing energy production as a new topic in the Physics curriculum. Our results show the energy panel debate is a very effective method for teaching this topic.

Key words: energy resources, energy production, energy assessment, scientific argumentation, teaching physics in high school.

Résumé : Nous présentons une méthode utilisant des discussions en table ronde, qui vise l'amélioration des connaissances en ressources et productions énergétiques chez les étudiants. La méthode a été utilisée avec quinze classes d'étudiants de 11e année dans des écoles secondaires de Roumanie. Pendant cinq ans, la recherche s'est faite sur le changement d'attitude des étudiants face à différents types de ressources énergétiques et comment ils acceptent les impacts environnementaux résultant de la production énergétique. Pendant ces années, nous avons noté plusieurs idées fausses concernant l'origine des ressources énergétiques et les processus de production d'énergie, avec leurs effets sur l'environnement. Afin d'avoir une solide compréhension de ces idées fausses, nous avons fait une étude à l'aide d'un test de 21 questions à choix multiples sur les ressources énergétiques. Le test a été complété par 720 étudiants du secondaire (9e à 11e année) de neuf écoles différentes en Transylvanie, Roumanie. L'analyse des données indique que les idées fausses touchant la ressource et la production énergétique sont similaires aux idées fausses identifiées dans d'autres publications de recherches faites aux U.S.A. Pour aider à créer une société bien préparée à prendre les décisions concernant les contraintes touchant la production énergétique, il est essentiel d'ajouter un chapitre au cursus de physique au secondaire. Nous présentons ici nos arguments pour l'introduction de la production énergétique comme nouveau chapitre à ajouter au cursus de physique. Nos résultats montrent que le format de la table ronde est un moyen très efficace pour l'enseignement de ce sujet. [Traduit par la Rédaction]

Mots-clés : ressources énergétiques, production d'énergie, évaluation énergétique, argumentation scientifique, enseignement de la physique au secondaire.

1. Introduction

This paper will outline the importance of learning scientific argumentation in school. There are many areas of science-based policy in which the public's input is vital. Many of these issues, such as air quality, local traffic management, genetic engineering of foods, energy production, and climate change, are complex. The science underlying these topics may not be straightforward and is often uncertain. In these cases, there may be empirical uncertainty due to a lack of data, uncertainty about the data processing of large numbers of values, or theoretical uncertainty as well. Even so, the public is able to draw reasoned conclusions. Developing an independent, informed view on a topic such as energy production, however, places a great demand on our society. Thus, it is one of the major goals of Physics teaching to help students construct sound arguments based on evidence gathered from different sources of reliable literature.

The demand for electrical energy production is rising worldwide, as there is an average increase of more than 250% worldwide in the last 50 years [1]. The 2017 U.S. Energy Information Administration's International Energy Outlook projects that world energy consumption will grow by 28% between 2015 and 2040 due to population growth and economic development [2]. Public pressure against the use of fossil fuels is increasing in many countries and debate is underway on how to develop the energy sector. Thus, a restructuring of this important economic sector is imminent. As the environmental impact of energy production on our planet is significant, it is important that all citizens and especially young adults be equipped with a basic knowledge about energy

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A.I.V. Vörös. Apáczai Csere János High School, Cluj-Napoca 400079 str. I.C. Bratianu nr. 26, Romania.
Email for correspondence: vorosalpar@gmail.com.

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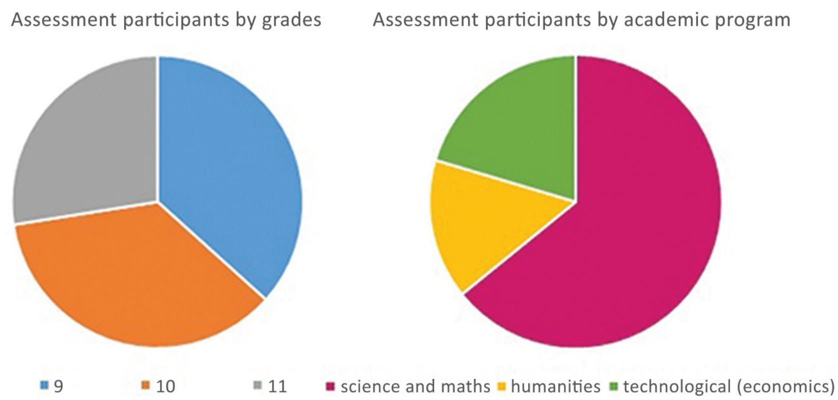
Fig. 1. Statistical data of the participants in the energy resources assessment (*a*, distribution by grades, *b*, distribution by academic program). [Colour online.]



resources and their impact on the environment so they will be able to make decisions and form opinions about future energy strategies [3]. As the topic raises a lot of controversial issues, it is an excellent opportunity to launch a debate with roleplay between students. Roleplay is a common pedagogical tool in the social sciences, and in some cases it is used for discussing climate change as well [4, 5]. However, these methods, which would facilitate the development of scientific argumentation skills, are rarely used [6].

Romanian school curricula almost completely neglect proper discussions about energy resources. In grades 6 to 8, energy resources and production are not in the core Physics curriculum, only in the 7th grade is there an opportunity to add a short chapter: energy and life (see order of Ministry of Education no. 3393/2017, annex no. 2). The high school curriculum for Physics has no topics related to this subject, only the 12th grade geography curriculum incudes a chapter about renewable and non-renewable resources (see order of Ministry of Education no. 4805/2000). Right now, the Romanian Ministry of Education has a plan to develop new high school curricula for the academic year 2021–2022. Therefore, this is the time to raise proposals for possible new topics. Many countries (UK, Australia, Hungary, some states in the USA) recognize the importance of including energy resource concepts in the national curriculum. An example is the energy systems project developed for STEM curriculum for K–12 students in the USA [7]. Important studies were made to facilitate a better scientific understanding of energy production topics and avoid misconceptions [8, 9].

2. Aim of the Research

One of the goals was to investigate the knowledge of 9th to 11th grade Romanian high school students about energy resources and energy production. This was done with the help of an assessment developed by Alec Bodzin and used in the US state of Pennsylvania for studying the knowledge of 8th grade students on energy resources [10].

The paper also aims to point out students' misconceptions related to this topic, and to show the effectiveness of discussing energy policies with students in the 11th grade.

The aim of this research is to point out the importance of teaching high school students about energy resources and energy production through a new method: energy debate, which is a debate about energy production policies. It has been used in Apáczai Csere János High School for the last 15 years. It was found to be a practical way to eliminate some misconceptions and to introduce a new chapter in the Physics curriculum.

3. Assessment of general knowledge about energy resources and energy production

To have a better understanding of misconceptions regarding energy resources and energy transformation processes in the production of electrical energy, a survey was conducted with a large sample of youngsters from high schools in Romania.

3.1. Participants in the survey

In this research, 720 students taught by thirteen teachers from eleven high schools in nine different cities in Transylvania, Romania, were involved. Of all of the students, 264 (36.7%) were in the 9th grade, 258 (35.8%) in the 10th grade, and 198 (27.5%) in the 11th grade (see Fig. 1*a*). The majority of students (573; 79.6%) were in theoretical (university prep) high school programs; only 20.4% were in vocational programs, most of which were related to economics. Of those studying in theoretical high school programs, 462 (roughly 64% of the total number of students) were on a science academic track (mathematics and computer programming or natural sciences), and 111 students were on a humanities track (social studies or languages) (Fig. 1*b*). All the students acquired only some fragmentary information about energy resources and energy production during their school studies. This was through a wider perspective on natural resources provided in 4th and 8th grade geography classes or eventually by the study of foreign languages (mainly English and German or French). Thus, most of their knowledge comes from media programs, online resources, and readings.

3.2. Assessment method

The Energy Resources Knowledge Assessment was adapted from the test used in Bodzin's study, which was a 39-item multiple-choice test on three main energy content areas: *i*) energy resources acquisition; *ii*) energy generation, storage, and transport; and *iii*) energy consumption and conservation. A modified version of the test was created to take a maximum of 15 min to fill in, so only 21 items were chosen from Bodzin's assessment [10]. There were 9 items regarding the first content area, 7 regarding the second, and 5 regarding the third. Assessment items are found in Tables 1, 2, and 3, respectively.

For easier data handling and processing, an online application (www.quizizz.com) was used, which allows several students from different locations to fill in the same quiz (maximum 5000) on any kind of device with a browser (PC, laptop, tablets, smartphones). Questions appear on each student's screen, so they can answer questions at their own pace and review their answers at the end. The application gives detailed reports at the class level or student level, which could be downloaded into an excel worksheet. The

Table 1. Item analyses of the energy acquisition: renewable and non-renewable energy resources content area (n = 720).

Item question	Correct answer	N	P–item difficulty level	Item discrimi-nation	Bodzin–item difficulty
1. What is the original source of energy for almost all living things on earth?	Sun	720	0.58	0.45	0.81
2. Which of the following is not a renewable biofuel?	Petroleum	720	0.71	0.49	0.51
3. Petroleum and natural gas come from	Plankton and sea life that are millions of years old	720	0.42	0.46	0.13
4. The term “renewable energy resources' means resources that …	Can be replenished by nature faster than they are consumed	720	0.52	0.57	0.57
5. Which energy resource is non-renewable?	Natural gas	720	0.65	0.56	0.36
6. Which fossil fuel is formed from swamp plants that lived millions of years ago?	Coal	720	0.32	0.31	0.17
7. Areas with geothermal resources include …	Geysers, fumaroles, hot springs, and volcanoes	720	0.69	0.44	0.48
8. Nuclear energy is considered NON-RENEWABLE because …	The uranium fuel sources are found in rocks that can be mined out	720	0.33	0.51	0.21
9. In the year 2250, most of the world's energy will likely come from …	A mix of renewable energy sources	720	0.61	0.52	0.58

Table 2. Item analyses of the energy generation, storage, and transport content area (n = 720).

Item question	Correct answer	N	P–item difficulty level	Item discrimi-nation	Bodzin–item difficulty
10. Which type of electricity generation has the least environmental impact?	A geothermal power plant in a hot earth area	720	0.24	0.37	0.14
11. What does it mean if an electric power plant is 35% efficient?	For every 100 units of energy that go into the plant, 35 units are converted into electrical energy.	720	0.40	0.41	0.36
12. Most electrical energy in Romania is produced from …	Coal	720	0.32	0.48	0.22
13. Photovoltaic cells convert … directly into electricity.	Light energy	720	0.68	0.56	0.43
14. Which is an advantage that geothermal power plants have over fossil fuel burning power plants?	Geothermal power plants do not have to transport fuel.	719	0.30	0.38	0.22
15. In a hydroelectric dam facility, water pressure in the reservoir forces water to turn a turbine that generates electricity.	This is an example of gravitational potential energy being converted to kinetic energy	719	0.28	0.40	0.20
16. The best place to build a new factory is at a location near an electric power plant because …	Less energy is lost during electrical transmission	717	0.40	0.60	0.34

application helped us to easily send the assessment test to all the participant schools and get back the results immediately, as soon as the test was completed. This facilitated data analysis. The assessment was filled out as a homework project (anyone with the code of the project could complete it within the given period of time) in the last week of the 2018–2019 academic year.

3.3. Findings

Table 4 displays the summary statistics of the students' knowledge about energy resources and production. For each correct answer students got one point and zero points for wrong ones; thus the maximum score was 21. Mean scores for the entire assessment group reveal similar misconceptions and a low level of understanding, similar to that found in the existing literature [10–13] regardless of the surveyed students' country of origin (US state of Pennsylvania, Turkey, Thailand, New Zealand, or Germany). Most of the students do not realize the negative impact on the environment of so-called green resources, such as hydroelectric dams, solar plants, wind turbines, or geothermal power plants [14]. Many students think that in a very short time, more than half of a country's energy production could come from renewable energy resources.

The mean value shows that students could answer correctly on average only half of the items and the standard deviation is relatively high. We can observe a difference in the mean value according to the academic program in which the students are enrolled. Students with stronger backgrounds in the natural sciences have the best results. Students in the social studies or languages programs did better than students in vocational programs, perhaps because they were already stronger students, having been screened during the high school admission process in 9th grade,

Table 3. Item analyses of the energy consumption and conservation content area (n = 717).

Item question	Correct answer	*N*	*P*–item difficulty level	Item discrimi-nation	Bodzin–item difficulty
17. Which uses the MOST ENERGY in the average European home in one year?	Heating and cooling rooms	717	0.46	0.47	0.25
18. Which uses the LEAST ENERGY in the average European home in one year?	Entertainment (TV, computer, video games)	716	0.36	0.38	0.10
19. What do we use the most petroleum for in Romania?	Transportation	716	0.56	0.47	0.30
20. Which energy source is likely to run out first?	Petroleum	714	0.67	0.49	0.30
21. The amount of electrical energy we use is measured in units called …	Kilowatt-hours (kWh)	713	0.66	0.56	0.18

Table 4. Energy resources and energy production assessment results based on the academic programs (n = 720).

Students' academic program	*N*	Mean scores	Standard deviation
All academic programs	720	10.54	3.9
Mathematics and computer programming or natural sciences	462	11.53	3.7
Social studies or languages	111	9.32	3.1
Vocational (economics, tourism, etc.)	147	7.61	3.2

and also because they take science subjects as part of their core curricula in 11th grade, while vocational students do not.

Item analyses were conducted by including item difficulty level and item discrimination of each item. Item difficulties ranged from 0.24 to 0.71. Two items had item difficulty levels (*P* value) less than 0.3 and nine items had a *P* value between 0.3 and 0.5, which were high difficulty level items. Nine items were of medium difficulty, with a *P* value ranging between 0.5 and 0.7. Only one item was of low difficulty level, with a *P* value above 0.7. Item discrimination ranged from 0.31 to 0.6. It should be mentioned that items with a low *P* value (very difficult items) have low item discrimination [15].

In the tables below, a detailed examination is made for each item separately, and data are presented separately according to the three energy content areas surveyed. The entire group of students is considered. Of course, if we separated the groups according to their academic background, we would see the same differences as presented in Table 4, with students on the natural science academic track producing slightly better results. Misconceptions were found in each group; only the level of the misunderstandings was different. Table 1 refers to the first energy content area, energy acquisition: renewable and non-renewable energy resources. These results show that students from Romania have approximately the same knowledge about energy resources as students from Pennsylvania. Their slightly better performance could be because they are 1 to 3 years older and have much more experience.

It is striking at first glance that the only item from the whole assessment for which the performance of American students was significantly higher was the first one: Romanian students had just a 58% success rate, while the rate for American students was more than 80%. Almost 36% of Romanian students think that water is the original source of energy for almost all living things on earth, which shows a misunderstanding about energy sources and nutrition (item 1). A very high rate (71% and 65%, items 2 and 5) of students can distinguish between renewable and non-renewable biofuels. As for the definition of renewable energy resources (item 4), many students have some misconceptions. Students think that renewables do not produce air pollution (14%), that they are very efficient producers of energy (12%), or that they can be converted directly into heat and electricity (15%). Romanian students have a much better (but still not very good) understanding (42% compared with 13%) of the origin of petroleum and natural gas (item 3) than the American students. Many of them (21%) even think that petroleum and gas come from dead dinosaur remains. Similarly, many students were unable to name the fossil fuel formed from swamp plants that lived millions of years ago (item 6): a very high percentage (33%) of students think it is petroleum instead of coal (32%). Item 8 shows that many students do not have any knowledge about the energy producing mechanism in a nuclear power plant: in many cases (34%) they considered nuclear energy non-renewable because it produces waste that is very radioactive.

In Table 2, we examine the results obtained for the second energy content area: energy generation, storage, and transport. Data analysis revealed that the majority of students do not understand how different energy resources are converted from their source form to electricity. Students do not have a sound understanding of the environmental impact or the advantages of different energy resources in generating electricity. A long debate could be had about item 10 (the energy production method with the least environmental impact), as recent research has shown that geothermal power plants could cause earthquakes [14]. People have serious concerns about the environmental impact of nuclear power plants due to a lack of information about the security of modern power plants. This is shown in our results as well: students placed nuclear power plants on the same level as coal-fired power plants with respect to environmental impact (with only 8% indicating that nuclear power plants have the least impact). The proportion of students aware of the possible environmental impact of wind turbines (32%), hydropower stations (28%), and geothermal power plants (24%) was very high.

Students also have misconceptions about the definition of the energy efficiency of the power plants (item 11), as in many cases they indicated the correct answers as follows: every 35 units of energy that go into the power plant produce 100 units of electricity (19%), or from every 100 units of energy that go into the power plant, 35 units are lost (23%). The 12th item measured how well-informed students are. In Romania, for example, a fairly similar amount of energy is produced by coal, petroleum, or in hydropower stations. This is reflected in the students' answers as well: 17.5% of the students think that natural gas is the most significant source of electrical energy in our country, 20% think it is water, and 23% think it is petroleum.

Results show a very poor understanding of the advantages of different energy resources, as the responses to items dealing with both geothermal resources (item 14) and the best location to build a factory (item 16) were wrong at a similarly high rate. Energy

Table 5. Comparison of knowledge about nuclear energy of students in Romania (n = 188) and Hungary (using data from year 2007 in Radnóti's article).

Item question	Correct answer	*P*–item difficulty level	Radnóti–item difficulty
1. Which type of process goes on in a nuclear bomb?	Uncontrolled nuclear reaction	0.28	0.25
2. What do you know about the reactions going on in a nuclear reactor?	It is a controlled nuclear reaction.	0.40	0.36
3. In normal operational conditions how many times does the radiation level rise against the natural background level?	It rises with an insignificant amount.	0.26	0.40
4. Which type of power plant, in your opinion does not emit greenhouse gases?	Nuclear power plant	0.41	0.71
5. Is radiation sickness contagious?	No	0.32	0.51
6. Radioactive radiations are used for …	In all three cases	0.29	0.11
7. If a radioactive nucleus has a half-life of 1 year, how many nuclei out of 1.000 will remain in 3 years?	125	0.29	0.43
8. What do you think about nuclear energy?	Dangerous, but it can be used with proper safety techniques	0.69	0.49

transformation processes in a hydroelectric power plant (item 15) are not clear for students, as only 28% knew the correct answer.

In Table 3, the results of the third energy content area are presented: energy consumption and conservation. This field is best understood by students from Romania. For each item, a notable difference is observed between their knowledge and that of the students from Pennsylvania. Still, they have some misconceptions, especially about energy consumption, as for example, many of them think that we use the most electrical energy (item 17) for entertainment (20%) and for lighting the house (18%), probably because these are the appliances used the most by youngsters at home. As for the devices that consume the least energy (item 18), students identified entertainment correctly (36%), but many indicated cooking and storing food (25%) and lighting the house (21%), which could be, in some cases, a correct answer, as the majority of households have started using efficient LED light bulbs in the last few years. It is not surprising that our students had a much better knowledge of the units of measurement of different physical quantities (item 21), as our Physics curricula put a lot of emphasis on it.

3.4. Acceptance of nuclear energy

To have an overview of the knowledge and attitude of youngsters towards nuclear energy, we conducted a survey of 188 students from the 9th to 11th grades. The study shows a surprisingly high level of acceptance of nuclear energy based on a low level of knowledge. The questionnaire consisted of eight items with four possible answers each, based on a study made by K. Radnóti in the last three decades in Hungary on students from the 12th grade [16]. From the results shown in Table 5, it can be concluded that less than a third of the students know the answer to the majority of these questions. Students best knew that in a nuclear power plant, a controlled nuclear reaction is going on and it has the least effect on the environment in terms of greenhouse gases [17]. Students think that radiation level due to the normal operation of a power plant could rise several times. They also have little knowledge about radiation sickness, as many have not heard of it. Only some students know that radioactive radiation is useful in destroying cancer tumors, inspecting welds, and sterilizing agricultural products. The concept of half-life of radioactive decay is also misunderstood by students. Although students in Romania know less about the phenomena taking place in a nuclear reactor than their fellow students from Hungary, approximately 70% of the students would rely on nuclear energy.

4. Learning about energy resources and production through energy debate

The energy debate was first used with 12th grade students, later it was included in an optional environmental Physics and Geography course developed for 11th grade students. At this age, students get sufficient background information on the topic and their intellectual development is high enough that they can analyze complex processes such as energy production strategies. They are also capable of argumentation based on sound documentation. The experience of these years show that students are easily engaged by this subject and were open to making additional efforts to acquire the required information.

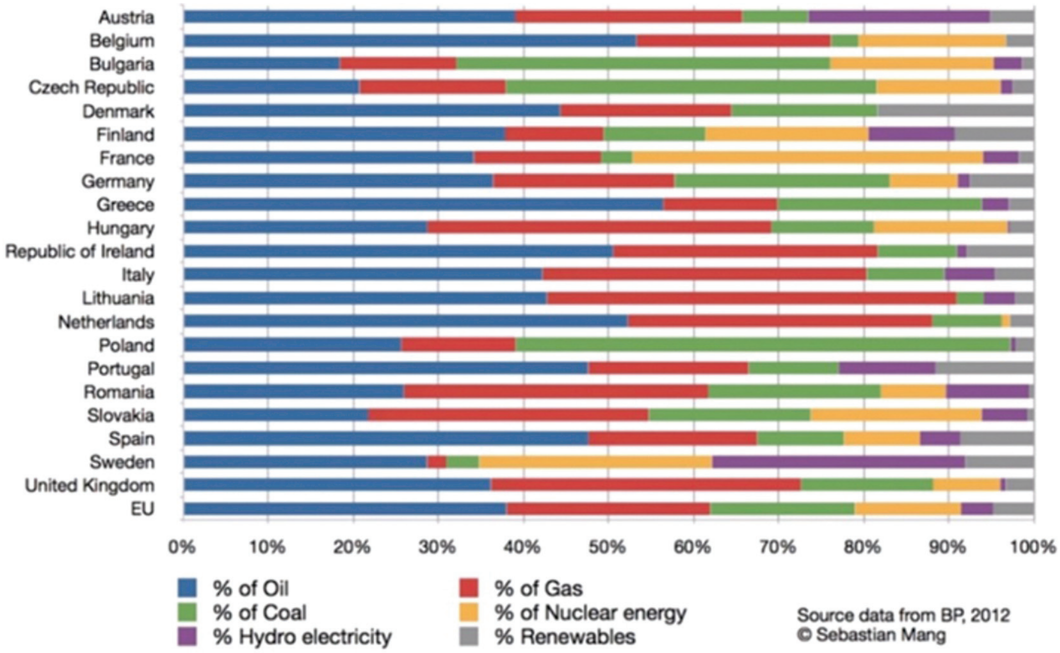
4.1. The energy debate method

Argumentation can play a central role in science and in learning about science. Nonetheless, we rarely use methods that help develop scientific reasoning [6]. In this subsection, the energy debate method is presented. This particular debate method consists of four different parts, for which six lessons are allocated: the first lesson is an introduction (first part), two lessons are for preparatory discussion (second part), another two for the effective debate (third part), and the last for the discussions after the debate (fourth part).

4.1.1. Introduction to the panel debate

In the introduction, the teacher presents the topic of the debate: students have to put themselves in a roleplay situation as participants of a live broadcast TV show with a thematic panel debate about the future of energy production for their region, in our case Transylvania. It is important to get the students deeply involved in the debate and it is more probable that a student will be able to get more relevant data about local energy production than about some remote region. During this class, students get a short introduction to current energy production issues and they can propose guests and experts to invite to this "TV show". As they put themselves in the role of the moderator of the show, students propose several possible speakers to invite: experts on different energy resources types (solar, nuclear, wind, hydroelectric, fossil fuel, geothermal, biomass, or other renewable energy), environmental activists, politicians (mayor of our town, prime minister, the minister of finance), geologists, or European Union energy policies experts. Some roles can be taken by several students, such as environmental activist, because it is important to let students get involved in a field of their interest [18]. Students less motivated

Fig. 2. Energy mix of countries from the European Union in 2011 https://creativecommons.org/licenses/by-nc/4.0/ [21]. [Colour online.]



about this topic or those with weaker communication skills can act simply as observers of the debate. The task for them is to write a critical evaluation of the panel debate and, if possible, to present it in the evaluation part of this process.

4.1.2. Preparation, a global view

After the introductory phase, some major problems about usable energy production (mainly electricity) are reviewed: *i*) the need for energy is increasing as the population and standard of living are rising worldwide, *ii*) there is a need to decrease the costs of energy production using technological innovations, *iii*) power plants are depreciating in time and need future investments and modernizations, and *iv*) the environmental impact of power plants should be reduced.

It is important to familiarize students with the units of measurement used in energy production to compare the effectiveness of different power plants. The energy mix (the distribution of the various energy sources) of different countries is presented (see Fig. 2) and discussed with students. We analyze data regarding the extent of carbon dioxide emissions associated with energy production per country. For example, in Fig. 1 the Netherlands and Poland stand out with a large share of fossil fuels. In the case of France, the large share of nuclear energy is discussed, while Sweden is the top country using renewable resources. The last topic in our discussions is local energy production, which could be followed by detailed updated daily data on the website of the Romanian National Energy Production Agency (www.sistemulenergetic.ro), a valuable and reliable source of information. We could discuss the variation in daily energy consumption of the society and sources of the energy production that could follow these short-term variations. Seasonal energy use changes are discussed as well, so as to provide a better view of the complexity of the national energy production system.

In this preparatory phase, each participant in the energy debate gets individual guidance for their role with some relevant printed or online resources regarding their field of interest. Students have to do research to find additional resources and create an outline of their presentation for the debate. Students are expected to gather information about the costs of building and operating a power plant, study the human resource needs for each type of power plant, and the environmental impact of each.

4.1.3. The energy panel debate

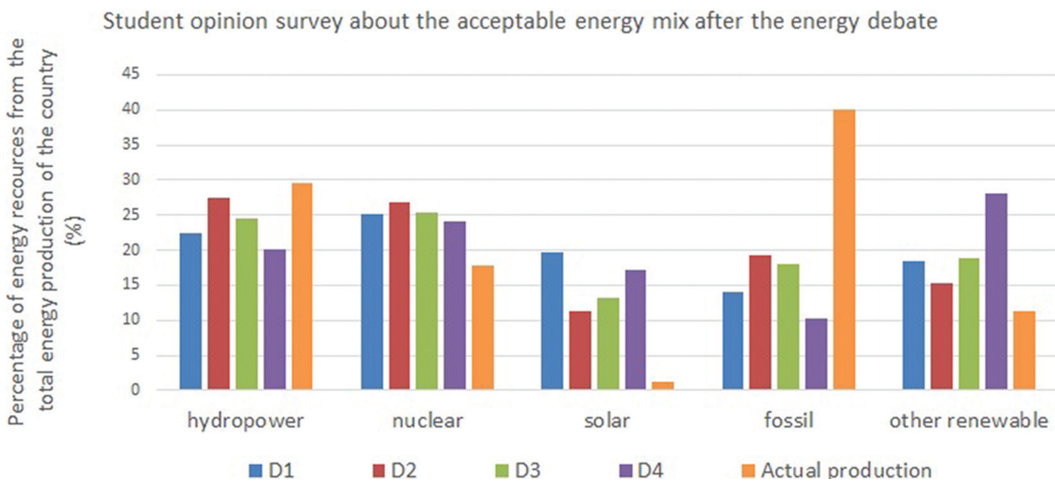
The activity is organized in a double lesson format (2 × 50 min), usually without a break, as students are so highly motivated that they do not ask for one. The arrangement of the classroom is important to create the conditions of a roundtable discussion, as seen in Fig. 3. The observers are located outside the circle as they take notes, and they can have questions or comments during the panel debate. Students prepare nametags with their roles stated on them. Usually they do this spontaneously without being asked. A general mode of progress of the energy debate is described as follows. Progress depends very much on the attitude of the class involved and also to a large degree on the personality of the moderator.

A possible course of the debate is as follows. The main role is that of the moderator of the debate, also a student, who starts with a short keynote speech to present the framework of this debate and some general information regarding the need for a new energy strategy of this region. The moderator first asks the energy experts in different resources to speak. After the presentations delivered by each expert, there is an opportunity for reflections by the environmental activists, with the expert having an opportunity to reply. Students in the role of politicians may pose questions as well to gather information. The European Union energy policies expert is next and presents the main power plant types that are financially supported by the EU. This is followed by the geologist's presentation about possible energy resources in the region, which could be used in the future. Finally, the politicians present their policies for the energy production sector. After their statements, energy experts and environmental activists may come forward with additional proposals or criticism of the views presented. At the end, the moderator says some final words and sums up the main conclusions of the debate.

It should be mentioned that in most cases, 11$^{\text{th}}$ grade students have already developed a strong culture of debating: they take their roles very seriously, can pose critical questions, and give

Fig. 3. Energy debate under progress in 2018. (Photos taken by A.I.V. Vörös). [Colour online.]

Fig. 4. Survey of student opinion after the energy debate about the acceptable energy mix compared with the actual energy production in Romania (www.sintemulenergetic.ro, 2016). [Colour online.]



structured answers regarding the topic. Experts deal with a lot of new information and in many cases their opinion is relevant.

4.1.4. *Discussion after the debate*

The last activity after the energy debate is the evaluation itself, during which students with the role of observers point out the main, essential elements of the debate. Usually they tend to be very critical as well, but this highlights the fact that during the activity they gathered a lot of new information.

In many cases, students report a fundamental change in attitude towards specific energy resources. In general, they outline misconceptions regarding renewable energy resources, such as the misleading term “green energy”, which gives the impression that these resources have no environmental impact and could be used on a large scale. Another strong concern is about nuclear power plants, but many students discovered through their classmates’ persuasive arguments that these, if regulated, could be an acceptable alternative. An important part of this activity is the teacher’s strong reliance on the pupils; the teacher must not interpose with any remarks during the debate. Only during the evaluation phase does the teacher give feedback to each participant and correct any erroneous information.

4.2. Evaluation of the energy debate method

The debate method has multiple positive effects on students’ intellectual development: it can build self-confidence, increase verbal skills, and it leads to open-mindedness and critical and logical thinking [19]. In the last five years (2014–2018) a study was done at the end of the energy panel debate activities on the effects this method has on students’ attitudes towards energy production. Each year, one class in our school participated in this activity. After each debate, a survey of students’ opinions was taken on the following question: what is the energy mix that you would accept for our region in the future (up to the year 2040). They had to come up with an optimal percentage for the five main energy production types from the total energy production of the country. Students knew the actual production from the above-mentioned website of the national energy production agency. It should be mentioned that only in four of the last five years did the activities adhere to the precise methodology presented above. In 2015, the activity was organized without the second part, the “preparation, a global view”. In that year, students did not get any guidance, rather, they had to gather information on their own, and they were not given suggestions on bibliographical resources.

Debate 1 (D1) took place in 2014 with 28 students, debate 2 (D2) in 2016 with 24 students, debate 3 (D3) in 2017 with 26 students, and debate 4 (D4) in 2018 with 24 students. Figure 4 summarizes the results of the surveys on the optimal distribution of energy production types. It presents the average values proposed by the students from those years in which the activities were conducted, in accordance with the methodology. We can observe very similar attitudes among the students. The differences merely reflect the effectiveness of the presentations by different students playing the role of energy experts: in 2014 one student was very persuasive about using solar panels; in 2017 a student made very strong arguments for other renewable resources, especially geothermal ones, which could be a very important resource in Transylvania, whereas in 2018 a student was convincing about the negative impact of hydropower stations on the environment.

The energy debate activity in 2015 (D5) was used as a control group to see how students can process information and data

Fig. 5. Comparison of a control group (D5) with the average of the other four groups (D1–4), participants of the energy debates, and the actual production in 2016. [Colour online.]

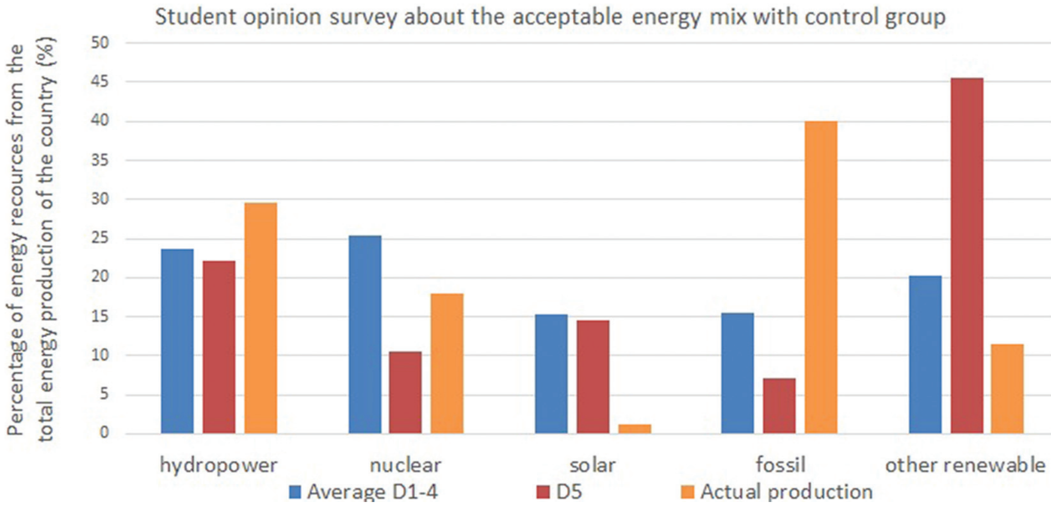


Table 6. Efficiency analysis of the energy debate method through the energy resources knowledge assessment.

	Test group		Energy debate group			Test group		Energy debate group	
Item no.	N_1	P_1–item difficulty level	N_2	P_2–item difficulty level	Item no.	N_1	P_1–item difficulty level	N_2	P_2–item difficulty level
1.	462	0.65	24	0.83	12.	462	0.36	24	0.54
2.	462	0.77	24	0.95	13.	462	0.76	24	0.91
3.	462	0.47	24	0.67	14.	462	0.32	24	0.62
4.	462	0.60	24	0.91	15.	462	0.30	24	0.57
5.	462	0.73	24	0.91	16.	460	0.46	24	0.67
6.	462	0.34	24	0.54	17.	460	0.51	24	0.71
7.	462	0.75	24	0.91	18.	460	0.39	24	0.54
8.	462	0.38	24	0.62	19.	459	0.61	24	0.83
9.	462	0.67	24	0.91	20.	458	0.72	24	0.95
10.	462	0.27	24	0.46	21.	457	0.71	24	0.87
11.	462	0.47	24	0.79					

about energy resources and energy production without any preparation and guidance. The same discussion and evaluation were done with this class as well, with the same question posed about the future of the energy mix in our region. As we can see from Fig. 5, after the energy debate the attitude of students showed the same misconceptions as those reported by the other students in their final remarks on their knowledge before the energy debate was taken. The control group thinks that in a relatively short period of time, solar power could have a 15% share and other renewable resources altogether a 45% share of the total energy mix, largely substituting for nuclear (10%) and fossil fuels (7%), which they strongly reject. Their views appear to be based on superficial information.

In the last part of this research, the knowledge acquired by students who took part in the energy panel debate was measured. The same energy resources knowledge assessment used in Sect. 3 was completed by one class (24 students) that participated in the energy debate activity. They filled out the assessment one year after they took part in the energy debate. This class was on a mathematics–computer programming academic track. A significant difference is observed compared to the subset of 462 students who were enrolled in a similar academic program but, did not participate in the energy debate program (test group).

The results presented in Table 6 show that this group understands better the differences between renewable and non-renewable resources. They also understand somewhat better the mechanisms of electrical energy production. The energy debate group had a mean value for the 21-item assessment of 16.14, while the test group had a value of only 11.53. Therefore, we can see a difference of 40% in favor of the energy debate group. In this group, ten items were of low difficulty level (with an item difficulty level above 0.7) and the rest of the items were of medium difficulty (with a P value ranging between 0.5 and 0.7). This shows that the knowledge acquired through the energy debate remains in the long term, thereby demonstrating the effectiveness of the method.

The energy debate method is also useful as an alternative summative assessment for physics knowledge at the end of the 11th grade [20].

5. Conclusions

A comprehensive energy resources knowledge assessment measured the knowledge of 9th to 11th grade students (ages 15–17). A total of 720 pupils took part in this assessment. It was found that this sample group had low to medium understanding of the energy production processes. We found similarities to assessments made in other countries. Our test group had a better understanding than the 8th grade students from Pennsylvania examined by Bodzin, who had a low level of understanding. This could be explained by the more advanced age of our students, who may have acquired more information on the topic outside of school, since they had not encountered this topic in any of their school subjects.

In Subsect. 3.3., many misconceptions related to energy resources and energy production processes were presented, based on the Energy Knowledge Assessment done with a significant test group (462 students). As the same test was completed with students taking part in the energy debate, a relevant shift in comprehension of energy resources and production knowledge was revealed. This is shown by an increase of 40% in their knowledge about this topic. This shows the effectiveness of the energy debate method and the importance of discussing energy policies with students in the 11th grade.

This study investigated the impact that the energy panel debate, as a new method, had on the students' attitudes. The paper gives a detailed description of the method used by the author in the last 15 years. The research conducted on the last five groups of students shows the importance of the discussion and preparation phase of this activity, as this helps students to better understand energy production systems and to clarify pre-established misconceptions. The results in Table 6. show that, due to the energy debate method, students acquired a deep understanding of renewable and non-renewable energy resources, and furthermore, most of the misconceptions were corrected.

While many countries dedicate an important role in the Physics curriculum to teaching energy resources and different processes of energy production, in Romania this topic is completely neglected. Students' involvement and the high level of interest in the problems discussed in the energy debate is a convincing argument for the introduction of this new chapter in the Physics curriculum in high schools, especially in the upper grades, such as the 11th or 12th grade. A possible way of approaching this topic would be the energy debate method.

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