The Future as a Return to the Past – a Look at the Concept of Energy and its Importance in Education

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Abstract

Energy has been part of the physics curriculum from time immemorial. At first it worked in the field of mechanics, electricity and magnetism, nuclear physics and gradually its knowledge about reached the point of knowledge, when it began to charge and develop the field of quantum mechanics.
If we look at the latest knowledge of science, we will find that physics itself is not the only science that deserves new discoveries. New discoveries depend on knowledge of other scientific disciplines.
In our paper we look at the approach of the concept of energy in the educational sphere of physics from an ontological point of view. Furthermore, we analyzed the concept of energy in science textbooks - chemistry and biology, where we highlight the areas that are connected by the phenomenon of energy transformation. Finding intersections between science subjects specified areas of energy transformation that we focused on when determining whether students perceive the concept of energy from a holistic perspective. In addition to the analysis of the content of textbooks, we focus on the conceptual equipment of grammar school students. The research sample consists of 200 students who participated in the creation of concept maps focused on the concept of energy. In this paper we compare the conceptual structure of students in primary and secondary school. The analysis of textbooks as well as the analysis of students' conceptual equipment form a springboard for further progress on how best to enrich the physics curriculum so that teachers already know what constructs students will come up with, which is risky in applying new knowledge, finding misconceptions and removing properly incorporated into the knowledge structure.

Keywords *The concept of energy, Conceptual maps, interdisciplinarity links*

1. Introduction

In order to be able to contribute to the teaching process with something more beneficial and interesting for the students, we also have to look back to the past. We need to make an overview of what is already effectively implemented in teaching and vice versa, what could be supplemented or enrich and thus bring closer to students the concept of physics or a physical problem that is difficult for them to understand [1],[2],[3],[4]. There are many good new methods like remote experiments or computer-based experiments that perform several functions in teaching physics from motivation to successful demonstration of new knowledge that contributes to the correct understanding of new knowledge of students. In this article, we want to focus on understanding the concept of energy in students, which they create in their minds in the already implemented learning processes. We focus on the conceptual analysis of science textbooks for secondary schools in Physics, Chemistry and Biology. With this, we identified areas that are important in the teaching of energy to cover its meaning in all areas of science. It is such a view of energy that meets one of its characteristics and that is the transformation of energy. An interesting question for us is whether they know how to create such links and connections within science subjects, which are also related to the knowledge contained in the curriculum of other science subjects such as independent physics. The concept map is an observable demonstration of whether students can recall restore the conceptual structure focused on the energy in their minds.
Energy is one of the basic concepts in physics, which appears in all its areas from mechanics to quantum physics. This concept encompasses a very wide range of its definitions with respect to the area in which it mentioned. „*We use energy as a word in everyday communication with the obvious and in the free sense. It is not possible to make a simple definition that includes all its aspects. Therefore, even when teaching physics, it must be built gradually, from its simplest form in mechanics to general considerations*.” [5] This statement about the physics quantity of energy encourages us to avoid it in the school environment with its non-physical significance for students. What we can expect as a teachers? What concepts have our students? How will be the concept database of primary (in the text we use as elemetary) school students who will come to secondary (in the text we use as high) school? We sought answers to these questions using the conceptual mapping method. We expected

the general meaning of the concept energy in the concept maps of elementary school in a larger number, more than half of the concepts. However, this assumption has not been confirmed to us.

1.1 Ontological point of view in the educational sphere of physics

Scherr [6] distinguishes three main area of ontology about energy from a didactic point of view: energy as a metaphorical substance, energy as a stimulus to action and energy from a vertical point of view. Understanding ontology should lead to understanding of energy concepts from a professional point of view. The first area of ontology (energy as a metaphorical substance) includes the properties of energy (conservation, transmission, presence in objects, flow). The second area is understood as a stimulus that affects objects. The third understanding of ontology as a vertical position speaks of the arrangement of sets of vertical positions. In this article, we start from the first type of ontological perception of energy as a metaphorical substance. We specifically focus on one of the properties of energy, which is the conversation of energy in the analysis of textbooks. It is this property that can ensure the concept of energy in all subjects, as pointed out by this fact Heron et. al. [4], where they claim that "*the basic role of energy is the unification of phenomena*" [4]. Students come to contact with it at various levels of education.

2. Methodology

We present the results of the analysis of science textbooks in Chapter 3. These are textbooks of biology, textbooks of chemistry and physics for secondary schools. They are intended for students of the first and second year of high school (age 14 to 17 years). We selected terms that are related to the concept of energy from individual thematic units and curriculum. We wrote them into the program Gephi, which created a network of given concepts. Every single term represents a node, and we have expressed the relationship between the terms using edges. We marked the terms from the chemistry textbook in red colour, the terms from biology in blue colour and the terms from physics in green colour. The network created in this way helped us to identify concepts with technical meaning that should appear in the student concept maps, which we analysed in section 4. In the results, we listed the most common technical concepts among high school students and elementary school pupils. We observed how the number of technical terms changed in comparison with commonly used terms. We explained to the students of high school the principle of creating a concept map as well as its use in learning due to nationwide distance learning in Slovakia for Covid-19 using the webex videoconferencing system. We attached a questionnaire to the students to the concept maps. The questionnaire had open questions about energy to specify their thought processes and ensure the correct analysis of their concept maps and classification of concepts into the category of concepts. The work by Novak [7] helped us how to tutor students and pupils to create concept maps by the correct procedure. Students could create a concept map manually or using freely available programs.

3. Analysis of textbooks and concept maps created by students of high school

„*Energy permeates all areas of physics, in which it appears in several forms. In general, we do not find an area in science where energy does not play a role. Energy can explain physical as well as biological phenomena, while not avoiding discussions in the socio-political field*" [3]. There is reason why we looked at the content of textbooks of physics, textbooks of biology and textbooks of chemistry, where we looked for areas related to the transformation of energy that which permeates all science subjects, and thus creating a holistic view of the energy. The content of the given subjects should be gradually built into the knowledge network of the student. This network should carry information of concepts in the transformation of energy in individual science subjects. We have selected thematic units and specific curriculum in which the transformation of energy appears by analysing textbooks of scientific subjects. We chose the concepts which high school students should incorporate their knowledge structure from the given topic. These concepts are illustrated graphically using the network created in the Gephi program in Fig. 1. We refer to the displayed concepts as technical concepts.

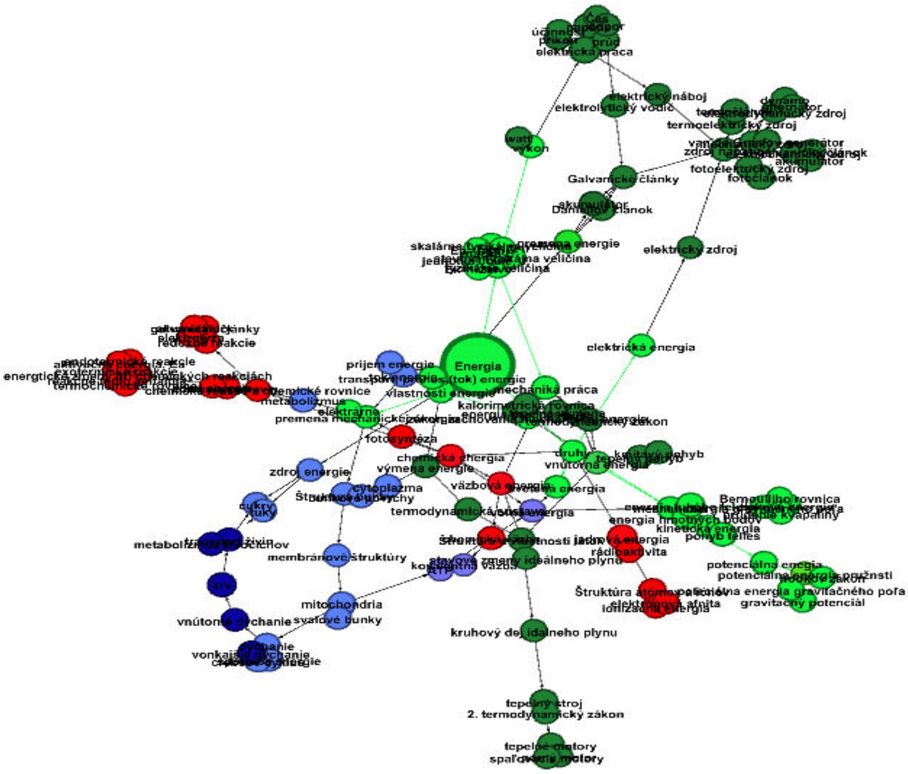

Fig.1. Technical concepts of energy and their connection in biology, chemistry and physics textbooks (biology – blue colour, physics – green colour, chemistry-red colour) for first and second year of study in high school in program Gephi.

We have identified areas, according to the captured relationships and connections between the concepts, that relate to the transformation of energy connecting all the mentioned scientific objects and thus creates a global view of energy. These areas are: Thermodynamic law, electrolysis, chemical bonding, metabolism, transformer, radioactivity, Bernoulli's equation, mechanical oscillator, sound, power station.
The individual identified areas related to energy conversation inform the teacher where he has opportunity to emphasize the integrative and in the same time interdisciplinary nature of energy. We state the number of concepts mentioned in the student's concept maps who are on the high school in the first year and second year of study. These mentioned concepts are component of the network of technical concepts which is created on Fig.1. In the Table 1. we present the number of concepts mentioned in the student's concept maps and the number of concepts in the network created by program Gephi.

Sphere	**Concept maps**		**Gephi**	
	1st year ***N***	**2nd year** ***N***	**1st year** ***N***	**2nd year** ***N***
Physics	97	90	36	46
Biology	19	4	18	23
Chemistry	25	11	20	20
summary	**141**	**105**	**74**	**89**

Table 1. The number of concepts mentioned in the student's concept maps and the number of concepts in the network created by program Gephi.

Eight concepts appeared an average in the concept maps of the first year of study in high school. In one concept map of a first year student, were average represented, 87% of physics concepts, 10 % of biological concepts and 6 % of chemical concepts fall on average. Nine concepts appeared of an average in the concept maps of the second year of study on high school. In one concept map of a second year student, were average represented, 94% physics concepts, 5 % biological concepts and 2% chemical concepts.

4. Comparison of concept maps of pupils in elementary school and students in high school

We compared the conceptual maps representation of the concept energy in high school students and elementary school pupils. Eleven concepts appeared of an average in the concept maps of the students on high school. All students of high school (129) used 1414 repetitive concepts in their concept maps. Students mentioned 111 concepts from physics, of which 22 concepts from the field of energy, 20 concepts from the field of energy properties, 45 concepts from the field of energy as a physical quantity, 24 concepts indirectly related to the concept of energy. Common concepts were mentioned by high school students 45 concepts were mentioned in the field technology, 72 concepts in the field of biology. In one concept map of second year student, were average represented, 75% physics concepts, 7 % biological concepts,4% chemical concepts, 17% technology concepts and 3% common concepts.
Ten concepts appeared of an average in the concept maps of the nineth year pupils of study in elementary school. All pupils of nineth year in elementary school (31) used 308 repetitive concepts in their concept maps. Student mentioned 75 concepts from physics, 28 common concepts, 7 concepts from chemistry, 38 concepts from technology and 14 concepts from biology. In one concept map of a nineth year student, were average represented, 53% concepts of physics, 25% common concepts, 4% chemical concepts, 10% technology concepts, 7% biological concepts.
In the Table 2. present an overview of the comparison of concepts mentioned in the concept maps of high school *G* and pupils of elementary school *E* whose were most frequently mentioned. We have selected the 5 most frequently used concepts from each field (physics, biology, technology, chemists, common). The number *N* of concepts used is given in parentheses.

Physics				Common			
G (N)		***E (N)***		***G (N)***		***E (N)***	
kinetic	108	heat	11	sun	35	sun	17
potential	95	magnet	8	water	33	light	11
electric	80	electric	7	wind	26	wind	7
Joule, J	70	electricity	7	light	21	electric motor	7
thermal	63	lightning	6	run	6	battery	5
		friction	6				
Chemistry				**Biology**			
G (N)		***E (N)***		***G (N)***		***E (N)***	
atom	5	atom	4	nature	5	photosynthesis	4
chemical bond	4	core	2	sunlight	5	energy in body	3
binding energy	3	neutron	2	sugar	4	nature	3
chemical reaction	3	proton	2	respiration	4	sugar	2
chemical compounds	3	electron shell	1	photosynthesis	4	fat	1
				motion	4		
Technology							
G (N)				***E (N)***			
power station	23			bulb	8		
waterpower station	15			battery	7		
renewabl resources	11			nuclear energy	3		
coal, oil, natural gas	11			electrical appliances	2		
solar panels	11			solar power station	2		

Table 2. The most of 5 mentioned concepts in the concept maps of students in high school *G* and pupils in elementary school *E*

5. Discussion and conclusion

In this paper we compared the concept maps of high school students with the concepts contained in the network processed by the Gephi program. We also compared their concept bank with the concepts contained in science textbooks. The number of used concepts in the conceptual maps created by students of the first year high school exceeds the number of technical concepts in the content of the textbooks of physics, textbooks of biology and textbooks of chemistry. There is a noticeable difference in the number of technical concepts from biology and chemistry for second year students. They clearly outperform the concepts associated with the subject of physics. We can see a clear attachment to the perception of the concept of energy from the point of view of physics for second year students. The conceptual representation of chemistry is more than half, which is not as weak as in comparison with biological concepts. There are less than one fifth of the maximum possible achievement of the boundary of concepts that are represented in the textbook content. The reason that students mentioned more concepts in connection with physics than was determined by the analysis of textbooks is that they introduced more specific things to the concepts, respectively more specified some parent concepts. A larger conceptual database of physics may also indicate that concept maps were made within the subject of physics. It would be interesting to follow concept maps that they would process in a chemistry or biology class. Another possible reason could be that students are more tend towards physics, have to her the better relationship to her, e.g. to biology, with which we monitor the low number of listed concepts. The concept of energy appears in every area of physics what cannot be say about other science subjects. Students able to expand knowledge from primary school and at the same time apply it. The students of the first year of high school stated a total of half more technical concepts than the maximum value of the concepts for the content of the physics textbook for the first year. The students of second year of high school exceeded this limit by six concepts. The students of the first year of high school introduced more than half of the technical concepts in all areas. The students of the second year of high school were low below half the limit in the field of biology concepts. The students of the first year of high school are better like the students of the second year, because they mentioned more technical concepts in their concept maps. The number of students involved in the research were 67 students of first year study and 62 students of second year of study in high school. The students of first year of study to see a holistic view of energy. They can see it like energy is phenomenon which is the same phenomenon in the other subjects. Students of the second year of study see the energy from the one view and it is from the physics sphere. Therefore, we recommend that high school teachers use appropriate ways of involvement between different concepts of energy in their teaching. These were determined by the results of teaching and other areas that were determined by the results of teaching and other areas that were looking for this we were looking in area 3.

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