

The interdisciplinary approach in textbooks: A study on energy issues

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Abstract

In a globalized and constantly changing world, education must be continuously updated. This requirement plays a major role in scientific and technological education, since technology may undergo significant changes in short periods of time. In such context, our students need educational opportunities that allow them to link scientific and technological aspects to many other subjects and situations which are closer to their personal interests and responsible actions. How to help our young people to discuss issues that need the consideration and integration of a variety of disciplines? How to encourage them to participate in a responsible way?

In this study we focused on teaching and learning the nature of energy, and other related concepts, in science from an interdisciplinary point of view. We analyzed contents of secondary education textbooks and curricular guidelines, taking into account their importance as classroom resources, and discussed the level to which controversial issues were displayed, considering a multidisciplinary approach.

Results highlight a lack of consideration of environmental and social impacts derived from energy production and consumption, and also a lack of attention to interdisciplinary aspects. Attention given to renewable energies does not fit the present role of these kinds of energies in society, focusing more on non-renewable energies. Generally texts emphasize traditional energies without regard to the future possibilities.

Keywords

Interdisciplinary contents, Energy issues, Secondary Education, Textbooks.



1. Introduction

At present, education, whatever the matter from which it addresses its duties, has to take responsibility, and also the challenge, to include comprehensive and updated approaches. Education has to face up to this problem now more than ever because its mission is to enable each of us, to develop our talents to the full and to gain consciousness of our creative potential, including responsibility for our own lives and achievement of our personal aims (Delors, 1996). That is, education has to offer each person the tools to continue learning throughout life, in the context of a globalized world in constant change. Considering the features of the new society and the extent and speed with which the changes are taking place, this line of education must be continuously updated (Hodson, 2003; Lemke, 2006).

These requirements play a major role in scientific and technological education. If our goal is training citizens with skills for decision-making and participation, we must offer our students work contexts where scientific and technological components could be related to many other subjects and situations. Those contexts, sometimes, have to do with aspects at the frontier of science, comprising a variety of disciplines (Colucci-Gray, Camino, Barbiero and Gray, 2006; Nordine, Krajcik and Fortus, 2011).

Additionally, science education should become more humanized and closer to personal interests in order to provide meaningful educational scenarios. Zembylas (2007) emphasized the importance of emotions, which have to be fostered by science's teachers. Edwards, Gil, Vilches, and Praia (2004) call for attention on global situation of the world, and Hodson (2003) gave great importance to some abilities as comparing, selecting or discussing topics, because they affect the health of democracy. He refers to "politicize" the science curriculum, as the analysis of some of the new challenges concerning humanity would train students for responsible actions.

Holbrook and Rannikmäe (2007; 2009), ask themselves about the nature of Science Education for Enhancing Scientific Literacy and about the meaning of scientific literacy.

How to join the interdisciplinary content and values this changing society demand? How to help our young people to discuss issues that need to consider a variety of disciplines? And how promote their social participation? Searching for answers to these questions, the teaching approach based on socio-scientific issues, which gives prominence to ethical and moral reasoning, becomes relevant (Zeidler, Sadler, Simmons, and Howes, 2005). Another relevant approach is what Roth and Lee (2004) called "citizen science", which incorporates elements of science that are common in both social and personal spheres. Similarly, Lemke (2001) recognized that the view of science as a single valid path to knowledge, disconnected from the social, political, cultural beliefs and values of society, is as unrealistic as useless in teaching.

Holbrook and Rannikmäe (2007; 2009) proposed less emphasis on specific scientific content knowledge and more emphasis on teaching based on interdisciplinary contexts and socio-scientific decision making. Thus, priority is given to opening science teaching to interdisciplinary and social considerations, in order to promote the necessary understanding of science in its social context (Roth and Lee, 2004).

2. The Study

In this study we had into account those considerations in the analysis of proposals of the present Spanish curriculum of secondary education (Educación Secundaria Obligatoria, ESO) on energy-related issues, and how these topics are treated in a sample of textbooks for students.

The energy is a fundamental and unifying concept in science. Given its importance, and how close it is in everyday life, it is one of those concepts students have direct contact with, even before facing teacher explanations (Nordine, Krajcik & Fortus, 2011).

Its teaching and learning processes are complex, as it is reflected in the large number of studies that have been addressed over it (Solomon, 1983; Bliss and Ogborn, 1985; Kruger, 1990; Trumper, 1993 and 1998, Liu and McKeough, 2005; Domenech Gil-Perez, Gras-Marti, Guisasola, Martinez-Torregrosa, Salinas and Trumper, 2007, Lee and Liu, 2010, among others). For these authors teaching and learning the energy concept involves the analysis of other essential aspects, related to environmental, political and economic problems. A rigorous treatment of the concept is needed but, indeed, superficial and limited approaches dealing only with some individual aspects are predominant.

The problem of production and consumption of energy in our days, related to the need to promote sustainable development for humans and environment involves us and affects everyone in the planet (Martin and Prieto, 2011). We can find in it a large volume of content and a great deal of controversy. Moreover, current energy consumption is one of the most widely used measures of progress and welfare of society, and its steady increase is striking and unquestionable. There are many consequences associated to this problem, as the exploitation of natural resources. We must take decisions about what to investigate or how innovate in science and technology fields, in relation to energy which encompasses finding a resource consumption model that is sustainable for humans and for environment and, in turn, to meet the production demands of the economy in today's society (Pedrosa, 2008; Nordine, Krajcik and Fortus, 2011).

This problematic area is closely linked to some of the most current environmental problems, especially, those about climate change. Controlling greenhouse gases emissions requires reducing demands of energy from fossil fuels in favor of alternative energy sources. It involves and affects us all as inhabitants of the planet. In its analysis and its possible solutions, many factors are protagonist.

Some can be highlight, as:

- Social factors associated with concern for the survival of our living's standards which are linked to depletion of some resources, and the high availability of other

natural resources, that in the case of suitable technological advances, could be exploited at reasonable costs.

- Environmental factors, linked to the impact that the use of different energy sources, such as fossil fuels or radioactive components, have on the environment.
- Economic and political factors, linked to the high cost that citizens have to pay for the enjoyment of them, associated, in most cases, to the political interests of certain countries.

It is therefore a case where controversy is a key element, as well as the personal and social domain (Martin, Prieto and Jimenez, 2013). This raises the question that, in the current situation of "planetary emergency" (Gil and Vilches, 2006), the approach to energy issue should respond to different perspectives (ethical, political and cultural), and not only scientists issues (Jimenez & Sampedro, 2006). Pedrosa (2008) and Thomas, Jennings & Lloyd (2008) highlighted the importance of relating school learning of energy to everyday actions, because this will promote understanding about the environmental problems that are involved to obtain it, as well as its consumption. Furthermore, with this approach we encourage our students to take interest in science.

The education system has a key role in educating about the importance of the energy problem, and it is necessary to cooperate in taking the necessary measures. A relevant aspect to search is the grade of presence that the highlighter factors have in the way in which the science curriculum and textbooks address the energy problem.

3. The energy issue in the science curriculum of compulsory secondary education in Spain

The Spanish curriculum of Secondary Education (MEC, 2007 and CAA, 2007), determines what students should learn in relation to the energy issue. This curriculum, focuses on skill acquisition, states that the goal of compulsory education is that students

must acquire the necessary tools to understand the world around them, in order to be able to intervene actively and critically in society. According to OECD (2002), the concept of competence is the ability to respond to complex demands and perform different tasks properly, which involves a combination of practical skills, knowledge, motivation, ethical values, attitudes, emotions, and other components and social behaviors.

Our analysis was focused our on the different sections of the curriculum in which energy issues have presence: competences, skills, aims, content, assessment criteria and teaching methods. Our first aim was to determine what skills, related to energy issues, are included in the curriculum proposal to students acquire and develop.

We focused on the "Competence in knowledge and interaction with the physical world". A Royal Decree-Law (MEC, 2007) refers to it as the ability to interact with the physical world, both in its natural aspects and those generated by human action, to enable understanding events, making predictions of consequences and to improve and preserve conditions of life, of other people and other living beings. Central elements in this competence are those aspects more related to energy issues, as the responsible use of natural resources, environmental care, rational and responsible consumption and protection of individual and collective health as key elements of the quality of life. In addition, it highlights that the interaction with the physical environment demands an awareness development of the influence and changes that might be produced.

Addressing energy issues in the classroom can help to achieve certain specific aims which are important for scientific literacy, as, for instance:

- To apply basic concepts of natural sciences to explain natural phenomena, as well as to analyze and assess the impact of techno-scientific developments and applications on society.
- To adopt knowledge-based critical attitudes to analyze, individually or in groups, scientific and technological issues.

- To understand and assess the interactions between science and technology on society and the environment, with particular attention to the problems humanity is facing today.

The Royal Decree-Law 1631/2006 (MEC, 2007) emphasizes that students should understand problems associated to production, transport and use of energy, as well as the importance of energy saving.

The sequence of the above mentioned contents throughout the courses is:

Second year:

It is included the analysis and assessment of different energy sources, renewable and non-renewable, and also about the problems associated with production, transportation and use of energy, as well as awareness of the importance of energy saving.

Third year:

It is included the study of the consequences that human waste of energy has in the environment, considering the relationships between people and environment. Geological changes caused by the external energy. The energy we get from the sun.

Fourth year:

It is included the analysis of different energies in our lives, as well as advantages and disadvantages of different sources of energy. An analysis of the contribution of science to a sustainable future is also proposed, as well as problems and global challenges that humanity faces today: global pollution, climate change, resource depletion, etc.

If we do the same in the Order of August 10, 2007 (CAA, 2007), which develops the Secondary Education Curriculum in Andalusia, we observe that it emphasizes the responsible use of natural resources and the current energetic crisis and its possible solutions.

We can see how questions are raised in order to describe contents:

Natural resources and their responsible use

Among the relevant issues, directly related with the topic at hand, we find air pollution and other socio-environmental problems. These topics are introduced with the following questions:

What are the main causes of air pollution?

How does it affect us?

Is it harmful the greenhouse effect?

How could decrease air pollution?

What proposals are made worldwide to achieve it?

Is there any connection between our use of a resource (for instance, fossil fuels or forests) and some problems in our environment (such as global warming and desertification)?

The possible solutions to the energy's crisis

- Related to the energy problem:

Which of your daily activities need energy?

From where do we get that energy?

How much energy is available, how much does it cost?

How is that energy distributed?

What is the energy problem?

Is there really such a problem?

Which are the worldwide proposed measures to reduce it?

What do scientists and media mean when they refer to global warming? What might happen in the world if an increase on the average temperature would occur?

What countries would be affected mainly by this increase and in which way?

What might happen in Andalusia?

What measures are proposed to address this problem globally?

Which of these measures are the most appropriate?

- Related to energy savings:

What elements could we implement at home to make a better use of solar energy?

How could we save energy along its transport?

Which could be the consequences worldwide of saving energy on issues such as air pollution, noise, etc.?

Could we help to save energy by changing our habits in terms of everyday consumer goods, modes of transport we use, etc..?

How?

- Regarding energy sources:

What alternative sources could be used to replace fossil fuels?

Which are the advantages and disadvantages of these alternative energies?

Which are the environmental impacts of renewable energy sources?

As we analyze the content of our National Curriculum (MEC, 2007) and the curriculum of the community of Andalusia (CAA, 2007), we can see that both laws give importance, as content to be treated, to the energy conservation, analysis and evaluation of using different energy sources and their environmental consequences. In both cases there are recommendations to deal with the energy problems that society is facing today, and the possible solutions that must be developed to alleviate the situation.

In relation to teaching methods, the Andalusian curriculum (CAA, 2007, blocks 4 and 5), recommends to develop the content around solving energy problems. Explanations of

teachers must originate reflection on how we use natural resources more connected to us, and get on with the analysis of the consequences arising from such use, both individually and locally. It expresses that they should end with a reasoned assessment of the solutions that may be applied in relation to that issue. Suggestions are made in order to start with those content that is more related to the world which is directly perceived (activities and everyday situations), and move to the study of more complex phenomena as students are progressing.

Concerning assessment, both laws (MEC, 2007; CAA, 2007), recommend to evaluate the capabilities that were developed to recognize problems related to the energy crisis, to analyze and evaluate information from different sources, and to evaluate proposals for energy savings that society is posing. They also propose the assessment of knowledge and level of awareness of the fact of abuse being made on various natural sources, as well as creativity and appropriateness of the proposals made in relation to the energy problem and the responsible use of natural resources.

In general, this analysis shows how the curriculum and, therefore, the laws that are governing education in Spain, whether at the national or regional level, are well aligned with the teaching approach based on socio-scientific issues. In particular, these considerations demonstrate the importance given to the treatment of energy issues through an approach that highlight the most controversial aspects that concur therein, as are the pros and cons associated to the use of energy, or the social implications that derive from them (Pedrosa, 2008; Fernandez, 2010).

4. Research questions

Since a majority of teachers usually use textbooks as major resource, it is important to know how curriculum recommendations are reflected in them, and especially whether or not the contents related to the most controversial issues are dealt from a multidisciplinary approach.

The research has been guided by the following questions:

In the declarative content of the topics that are dedicated to energy and its different aspects:

- What presence do have the interdisciplinary aspects related to the issue of energy in the world today?
- What presence does have the impact that energy uses have in the environment and the society?

5. Data analysis and results

A sample of 36 textbooks from nine publishers with great presence in Andalusian schools was selected. The texts, 4 per publisher, correspond to the subject of Natural Sciences for 1st and 2nd ESO, and Physics and Chemistry, of 3rd and 4th year, addressed to pupil from 13 to 16 years old.

Data analysis began with a selection of chapters and sections in which energy, sustainability and renewable energy had a presence. Usually, these concepts appear in the context of issues devoted to the study of energy. The analysis was conducted by looking for, in the different parts in the declarative content of these chapters, the interdisciplinary aspects on the energy issue that are emphasized by the curriculum. The search focused on content related to the kind of use made of energy from different sources and the social consequences of it. Proceeding in this way, we configured, in a flexible manner, a set of categories within them (Bliss, Monk and Ogborn, 1983).

Uses associated with different energy sources

Descriptions and explanations about the use of energy from different sources in two different contexts, the Industrial and Domestic/commercial, were collected and organized.

In the industrial context, we have considered explanations about the use of energy that has been produced from large facilities, referring to the type of font, and how the process has been performed. In this way, eight categories were defined, which allude to the different uses depending on the facilities of origin (wind farms, hydroelectric plants, solar plants, geothermal plants, tidal energy plants, biomass plants, nuclear and thermal power plants). In the domestic/commercial context, we collected explanations about the uses of energy from different sources, in everyday activities.

As in the previous case, a subdivision was performed, but now, we considered the origin of the energy source (Sun, coal, natural gas, oil and radioactive materials). From our data, we detected a high interest on the uses given to energies from large industries in comparison to renewable energy sources. It highlights a tendency to emphasise energy production of wind farms, hydroelectric and solar plants. In contrast, plants that use energy sources from fossil fuels and radioactive materials were less considered. Attention that textbooks pay to the energy problem in the industrial context is even smaller. As in the previous case, less attention is paid to aspects related to renewable energies. As a positive aspect, we find out that three publishers collect at least three of the categories considered, and they do it in courses where the subject is compulsory for every student (1st and 2nd year of ESO).

Social consequences

They refer to contents that are related to the consequences that are generated by the consumption of energy from the different sources. We considered three kinds: environmental, economic and political. For all of them, we distinguished between non-renewable and renewable energy sources.

Data showed that implications which are more directly related to the impact on the natural environment have a greater presence than those associated with the social aspect, both economic and political. Having a look in detail, we saw that in relation to the

environmental consequences of non-renewable energy sources, all publishers included, in some of their courses, acid rain, greenhouse effect and production of waste radioactive nuclear plants, as adverse effects. Only three of them allude to contamination produced by released products that can be generated in its production and use.

Regarding renewable energy sources, all texts emphasized absence of polluting effects as advantages, and most of them alluded to disruption in ecosystems and visual impact as disadvantages. With regard to their presence in each of the courses of the ESO, the aspects that have been addressed in any case are included in more than two courses. It is of concern to see how other aspects are poorly treated and, when they are, in most of the cases, appear only in the texts of the second cycle. Most publishers refer to a number of aspects between 4 and 6. They all present the trend to emphasize the advantages of non-renewable energy and the drawbacks of renewable, from the economic point of view. The political consequences arising from the use of one or another energy source are reflected to a lesser extent than the economic and environmental consequences.

The political aspect that received greater attention (it appears in 5 of the 9 book publishers) is the dependency that exists between those nations possessing energy sources and those without them. In the development of this aspect, emphasis is on the difficulties that may arise in a country where the power supply is dependent from another country, and therefore, depending on its economic and political relationship. Only one of the publishers includes the 4 aspects, in a differentiated way, and even 2 of them on 2 years of ESO.

We could say that this publisher shows a different trend from the remaining 8 in terms of attention given to the political implications. It is also notable for being one of those that address a wider range of economic implications.

With regard to the other publishers, three of them did not consider this type of consequences and three did so only on one aspect and in a single course. It is also



interesting to note how, in the total sample of textbooks, only four publishers included at least one political aspect in their texts (1st and 2nd).

6. Final thoughts

Our results show a lack of attention to interdisciplinary aspects, which may provide us the learning opportunities we are looking for. We also find that the implications of economic and political aspects of the problem appear in a lesser extent than environmental implications. Moreover, our results also show that attention and space given to non-renewable energy in some key aspects, such as production aspects and implications, are greater than that devoted to renewable energy.

In this respect, we see that the texts emphasize traditional possibilities and not future possibilities, what leads us to conclude that the focus on the problem that curriculum presents is not reflected in the content of the texts we analyzed.

Edwards, Gil, Vilches & Praia (2004), in the same line of reasoning, argued that textbooks should make greater use of the context of real problems that currently humanity faces. We consider that, around the current energy problems, it is more likely we can promote awareness about the importance of energy in our lifestyle by promoting awareness of how far we depend on it.

Our findings are also in accordance with those of Garcia-Carmona (2008), who argued that concepts, laws, rules and techniques appear as first order, compared to technology and society aspects, which appear as 2nd order. We also highlighted a lack of consideration to environmental and, specially, social impacts, and their influence on political and administrative decisions on the uses and applications of electronics. The most controversial aspects of the problem, as well as its interdisciplinary nature, cannot be overlooked in a rigorous treatment of it, as they also contribute to the development of attitudes and values.



Considering our results as starting point, we agree with the proposal made by Colucci-Gray, Camino, Barbiero & Gray (2006), who emphasize the relevance of spending time and effort in the classroom on working issues such as: a) the concern for sustainability and savings in energy consumption, b) the impact of energy in our daily lives, c) our responses: kind of problems and kind of solutions, d) energy consuming activities, problems arising, etc. And we also agree with Lemke (2006) when he says that one of the contributions that science education can make to students and society in the XXI century is a science education with a focus on concerns and social issues of students, in order of getting arouse their emotional engagement with science learning. We strongly believe that this goal is a clue in order to achieve these new educational aims.

Some contributions to teaching practice.

Considering the importance that have the issues and situations that lead students to understand the links between consumption of certain energy products and the necessary resources to get the energy, as well as the advantages and disadvantages of the modes of production and consumption of energy from different sources, we think that they represent useful instruments in the development of the personal responsibility, and so they would receive more protagonism in the science activities included in teaching and learning of energy. The same argument is valid for the different consequences in the environment and society. The interdisciplinary nature of the analysis of these problems has potential in promoting a meaningful understanding, through the use of different variables that play a role on them. Our data show that many of them are frequently poorly developed or simply not included.

We consider it would be advisable to treat the energy aspect in more courses, due to the importance of the problem and because it can help to understand many of the real problems that exist in society. The way that many of the texts analyze these contents may hamper educational developmentin students, if previously we do not promote the



motivation to deal with the problem and, hence, to commit their participation in the search for solutions (Pedrosa, 2008). In our opinion, treatment of some real issues about energy in the science classroom should be considered together with an analysis of the society itself, and this includes economic and political aspects, which are privileged agents in decisions making.

Limitations regarding the research

This piece of research has been centered on the interdisciplinary nature of the energy problem and the way it is reflected in the science curriculum of Spanish compulsory secondary education and in a sample of texts books.

We have focused the study on the declarative content of the different chapters in search of the interdisciplinary aspects on the energy issue that are emphasized by the curriculum. Other aspects, for instance the analysis of concept and processes involved in the activities that books propose, as well as the kind of activities themselves, has not been included.

We are also aware that, in order to promote interdisciplinarity in the treatment of topics like this one of energy, we have to bring with us the science teachers' complicity. We need they open their mind in order to accept that, today, they cannot rely on them and consider they are doing enough, and recognize that what teachers need is not always included in textbooks. We are going to keep this research in the way of trying to promote and to stimulate teacher's willingness to apply these approaches and to open their perspectives from pure science to the interdisciplinary interactions, as well as their ethical, political and moral components which are involved in many of the problems that we, as humans, have to face in the twenty-first century.

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