ENERGY, FOOD AND SUSTAINABILITY

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ABSTRACT

Food satisfies a basic need of living beings, but in human society it has assumed many other meanings (cultural, social, ritual, etc.). The supplied energy to the human body is trivialized by the indication of the calories on the packaging but it is completely disconnected from the students' scientific knowledge. Some learning path focused on the energy aspects related to food is proposed. Starting with the most obvious ones (how much energy is available to the body by eating some food and how it can be related to the calories listed on the package) the students can explore the most hidden aspects of the topic, such as the energy cost for food processing, packaging, distribution, preparation and consumption. How much fossil fuel was consumed for the production of a portion of spaghetti? The concept of sustainability is introduced and the evaluation of the dietary practices according to this criterion is suggested, helping to form better informed citizens who are more aware about energy sustainability.

INTRODUCTION

The choice of designing learning paths in which energy, food and sustainability are interlaced arises from motivational reasons. Theoretical and empirical studies on the relationship between interest, motivation and learning process are widespread in educational research [1, 2]. From the educational point of view, it is essential to understand how and why students are involved in new topics and such approaches are effective [3-5]. Motivation and interest may facilitate the learning process increasing student involvement both in laboratory and in class discussions. Food plays an important role in students' everyday life, it allows to encounter complex systems and to examine them from an interdisciplinary point of view. Moreover, the intertwinement between energy and food is rarely deepened in school education.

The exploration of energetic aspects tightly related to food enables to design activities in laboratory which are much more interesting for students than the usual ones. Furthermore, energy is a relevant issue in physics and in science education and it can enhance the scientific literacy of people.

The main goal is to introduce to sustainability [6, 7] by using a scientific sight. In nature, when an animal population manages natural resources in an unsustainable way, the final outcome frequently leads to extinction. When a human society makes use of environmental resources in an unsustainable way, the main effect can be its collapse [8].

Since sustainability plays a central role in present and future for human societies, United Nations are promoting the 2030 Agenda for Sustainable Development containing Sustainable Development Goals [9]. In August 2012, UN Secretary-General Ban Ki-moon launched the Sustainable Development Solutions Network (SDSN) to foster a global network to mobilize academia, research institutes, civil society, and the private sector in pursuit of practical solutions for sustainable development. The regional hub for the Mediterranean of the Network is coordinated by the University of Siena [9].

In this context, educational pilot actions were developed in order to promote knowledge in sustainability and they are summerized in the next section. During the implementation, new learning paths in physics and science were developed showing how this topic can be useful for clarifying some relevant disciplinary knots in science education.

These early experiences were reserved to small groups of motivated students and few teachers were involved in laboratory. A relevant outcome was the request of developing learning paths for integrating these issues into ordinary didactic at school. An interdisciplinary learning path, articulated in activites in science and physics laboratories, involved all students of a small high school. The most significant aspects of this experience are reported in the following section. Results and conclusions are presented in the last section.

EDUCATIONAL ACTIONS IN PHYSICS FOR SUSTAINABILITY

Sustainability is an unavoidable issue of citizens' curriculum and scientific literacy, too often used and abused by mass media. It is increasingly present in contemporary society and recurrent in the media, in advertising and in the policy guidelines of organizations such as the EU and the UN. Physics can be useful for clarifying the scientific context in which many relevant issues of real world can be quantified.

Physics education can contribute to introducing sustainability by showing how investigation of the physical world is an unavoidable step in finding sustainable solutions, In particular, many methodologies and skills developed by physicists can be useful. A minimal list in this sense contains at least problem posing [10] and solving in complex situations, technical skills (like measurements, estimates, approximations, modelling) and how to interact in an interdisciplinary context.

Moreover, the Scientific Method is a powerful methodology at the base of physical description of nature and it is central in finding effective solutions in real complex contexts through the iterative process oscillating between hypothesis on which theoretical models are developed and experimental verification in the real physical world.

On the other side, for physics education in secondary school, sustainability can be like a Trojan horse that conveys the interest from everyday reality to scientific concepts, involving the students in new laboratory activities. Moreover, teachers can be engaged in professional empowerment and in active applied physics educational research.

Since 2014, educational activities were designed to introduce the concept of sustainability through meaningful activities in physics education. The main ones are the following:

Summer Schools of Physics [11, 12] briefly presented below,

USiena-Game [13], a match of a competition between 3-5 secondary schools performed at the university on specific themes (Stem cells, Sustainability, Europe). Educational tools designed in this contest were useful for the assessment in other actions,

Fostering best practices in school, supporting teachers in designing and realizing learning paths in physics and sustainability. An example is reported with some details in the next section. In each action one or more educational materials on energy and food were designed and tested with students.

Since 2006, 35-40 students from high school are selected every year to attend a full immersion summer school of physics in Siena countryside (the Pigelleto Natural Reserve or a historical small town, Pienza). The students (age 16-17) are proposed within the National Plan for Science Degree [14] by a network of schools in southern Tuscany. The focus of the summer school is always on physics laboratories, active and cooperative learning, peers communication. The 2014 edition, entitled Physics for sustainability. Science and knowledge for a better world, was focused on energy, food and marine plastic debris. There was an excellent feedback by students and teachers. The edition of this year was entitled Let's measure the world. Physical tools for finding sustainable solutions and reached the same results.

The sustainability was introduced in both summer schools by using analogies for visualizing concepts, for example to distinguish between oversimplifications, sustainable situations near to a breaking point, stable sustainability subject to changes in boundary conditions that can destroy it and finally to a sustainability based to natural laws and active practices (see Fig.l.)

Fig.1. Different types of sustainable situations are visualized by using the analogy of a system in stable or unstable equilibrium in gravitational field in various situations.

As example of activity, a laboratory on problem posing and solving is presented. The initial problem was to estimate a physical quantity in a real context relevant for the theme, then it had to be modelled, approximated, checked and the model had to be refined. Are there hidden variables? Which experiments can be performed for validating or confuting the hypotheses? Is the scale factor relevant? Search for problems related to the theme in local, intermediate and macroscopic scales. Is it possible to find sensible solutions? Which action could mitigate the actual unsustainable situation by involving my family and my friends? Or the whole school, or which other community can make the difference by assuming a responsible behaviour? The students discussed for choosing the problem and assess the physical impact. Is the proposed solution significant, economically viable, socially acceptable? Some teachers attending the summer school suggested to realize a learning path on food, energy and sustainability in their school for all students.

A PILOT IN A SECONDARY SCHOOL

An interdisciplinary learning path was designed and realized in a small high school (50 students aged 14-18, two physics teachers and a science teacher, a lab technician) in collaboration with the university.

The starting point was that the supplied energy to the human body by some food is usually trivialized by the indication of the calories on the packaging but it is completely disconnected from the students' scientific knowledge. Activities were introduced by open questions like: How much energy is available to the body by eating a portion of food and what is the relationship with the calories listed on the package? How much energy is needed for food processing, packaging, distribution, preparation and consumption? How much fossil fuel was consumed for the production of a portion of spaghetti? Or a banana? Can we measure these energies in laboratory or estimate them by looking for information in database or elsewhere? Is my favourite menu sustainable? What is its carbon or water footprint? The answers were searched by a preliminary discussion in class and followed by activities of problem posing and solving and/or through experimental activities in laboratory.

A science laboratory in which a device designed by students (see Fig.2.) was realised for measuring the calorie content of small quantities of an aliment. The apparatus consists of a metal support for the food, the combustion is initiated by a piezoelectric gas lighter away from the test tube in which there was a known amount of water. The measurings of the burned mass, the initial and final temperatures of the water allowed to estimate the calories in the food. Discussion on the results obtained by different groups for the some kind of food clarified that the apparatus gave only an estimate and not a quantitative result. On the other hand, a qualitative analysis for different food outlined a relevant boundary condition for the following measurements: the humidity.

Fig.2. Left panel: the experimental apparatus for evaluating the calories of foods made in the science lab, where a student was starting the combustion. Right panel: the apparatus during the combustion.

Since the beginning of the last century [15], calories in foods are measured by using a bomb calorimeter [16] to carry out the complete combustion of a solid or liquid substance in the presence of excess oxygen. The combustion reaction is initiated with electrical ignition. This type of constant-volume calorimeter, shown in Fig.3. on the left, consists of a small cup to contain the sample, oxygen (pressure 20-30 atm), a stainless steel bomb, water, a stirrer, a thermometer, a Dewar flask or an insulating container (to prevent heat flow from the calorimeter to the surroundings) and ignition circuit connected to the bomb.

The teachers and the technician soon agreed that this apparatus was not safe to use in an educational laboratory and too expensive. Thus, a modified bomb, shown in Fig.3. on the right, was designed, realized and tested by the university group.

In the modified bomb calorimeter, food samples are partially burned in a metal cylinder, immersed in a mixing calorimeter with water [17]. A constant flux of compressed air allows combustion, blasting hot flue gases through the water. The food sample is wetted by a small quantity of alcohol whose vapour is ignited by electric wires.

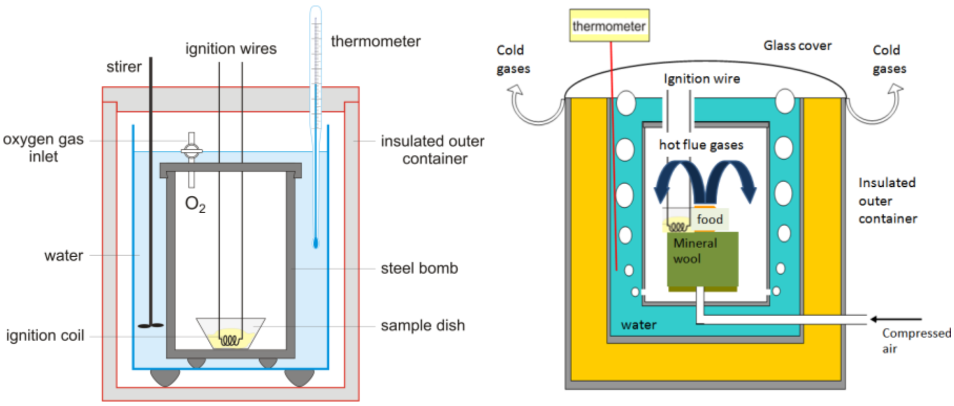

Fig.3. Left panel: Section view of a bomb calorimeter [18].
Right panel: The modified bomb calorimeter.

The heat balance is described by

$$\sum_i Q_i = Q_s + Q_{ign} + Q_{cal} = \Delta mX + Q_{ign} + C(T_{in} - T_{eq}) = 0. \qquad (1)$$

where Q_s is the heat generated by the combustion of the sample, Q_{ign} the heat from ignition (electrical energy and heat from alcohol's combustion), Q_{cal} the heat exchanged by the calorimeter, Δm is the burned mass, X allows to determine calories content, T_{in} and T_{eq} are the initial and final temperature of the water in the calorimeter, and C is the heat capacity of the calorimeter, determined by a calibration and usually referred as its "water value". The heat generated by ignition was determined by a series of measures with no samples, the electrical energy necessary for starting ignition resulted negligible while the contribution from alcohol's combustion was been determined. The new device (Fig.4.) allows to obtain full reproducibility in measurements and quantities are in good agreement with calories in database.

The learning path shows clearly that the science lab is focused on qualitative observations (useful and good for distinguishing the main contents of food, in terms of lipids, sugars and proteins). In school practice, a science teacher never proposes to estimate uncertainties or compare measured calories with food nutrient database. On the other hand, a physics lab is focused on quantitative measurements, uncertainties are estimated almost every time. The two devices explore complementary experimental aspects and together give a much deeper insight in natural phenomena.

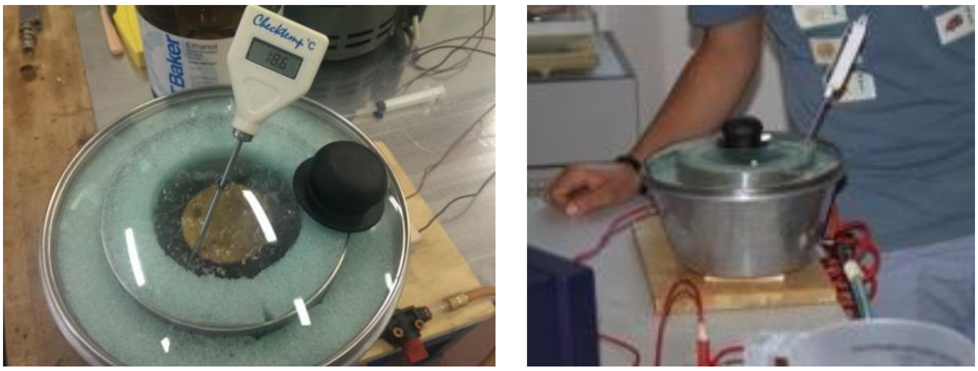

Fig.4. Left panel: Prototype of the modified bomb calorimeter showing the flow of air bubbles in the water. Right panel: the apparatus used by students for a measurement.

CONCLUSIONS

Food and energy are a good choice for introducing students to sustainability. Motivation and interest were enhanced in students and in teachers, too. New paths in laboratory were designed and remained available for curricular education. A clarification in basic topics was achieved, such as differences in estimates and measurements, or in qualitative lab compared to quantitative lab. The main result was the comprehension of the concept of sustainability in this context. All teachers are continuing and expanding these activities in the current year.

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