A science fair on solar energy with 6th grade primary school children in Greece

Nektarios Tsagliotis

Teacher-PhD candidate, Department of Primary Teacher Education, University of Crete, Greece

e-mail: ntsag@edc.uoc.gr

1. A thematic approach to science fair

A science fair appears to be an informal teaching and learning process, which can possibly interweave within teaching sequences or teaching interventions, in a sense of broadening the horizons of formal teaching and learning processes. A science fair mainly aims at developing positive practices and attitudes of children, within a framework of "hands on" science investigations and activities. Of course, this does not mean that the conceptual framework of children's ideas is neither ignored nor neglected. On the contrary, it appears to be strongly considered and elaborated in depth.

Children approach a particular topic, having their questions and interests as a starting point, in an attempt to deal with specific problems and/or every day instances, through a scientific investigation for deeper knowledge and understanding. They develop projects collaborating with each other in pairs or small groups, whereas teachers facilitate investigations and activities and usually facilitate the availability of a variety of materials for children to work with. The end product of a science fair is an open exhibition of children's work, where their projects and/or constructions are presented in public and usually judged, awarded prizes and distinctions (cf. Fredericks & Asimov, 1990; Van Cleave, 2000).

The science fair is considered within a *thematic* or a *cross curricular theme* framework and it is seen from the point of view of *a specific teaching and learning subject*. According to Beane (1997) a safe criterion to discern a *thematic* or a *cross curricular theme* approach, within the treatment of a particular topic or theme, is its actual way of design. In such a context, the central theme is taken as the starting point, followed by the treatment of ideas and conceptions related to the theme, alongside with actions undertaken or employed in order to investigate these ideas and conceptions. This kind of design is put into practice without considering the boundary lines amongst different school subjects (i.e. physics, mathematic, crafts, social studies etc.), since the focus is on the investigation of *the* particular theme and not the linking of the theme with various aspects of school subjects. In this sense, a *thematic approach* to a science fair is differentiated from a *multidisciplinary* or *interdisciplinary* approach, where the recognition of different identities of school subjects is strongly considered. The main focus appears to be on the contribution each school subject can have to the treatment of a topic or even the mastery of ideas, skills and processes included within the involving school subjects. In these terms, the actual treatment of a theme becomes a secondary issue moving back stage, whereas *multidisciplinary* or *interdisciplinary* issues come to forth, within the interplay of different school subjects.

A *thematic approach to a science fair*, which is strongly supported in this study, is based on a design where the investigation of a particular theme, for instance applications and uses of solar energy in every day life, comes into focus. The framework of study and the investigation of ideas and conceptions are being determined by the theme, but simultaneously shape or constitute its boundaries and limitations. The teaching and learning activities and the design of projects initiate from the investigation of the particular theme and are strongly related to questions and issues which are put forward during the course of the study. A holistic or spherical approach of the theme appears to be taken into account, whereas specific choices in the treatment of its aspects need to be considered in an attempt to achieve an internal congruity and point out interrelations amongst the chosen aspects. Nevertheless, the priority of choices, the educational setting, the situated characteristics of the thematic approach as well as time arrangements and limitations, constitute significant components that shape the framework under study.

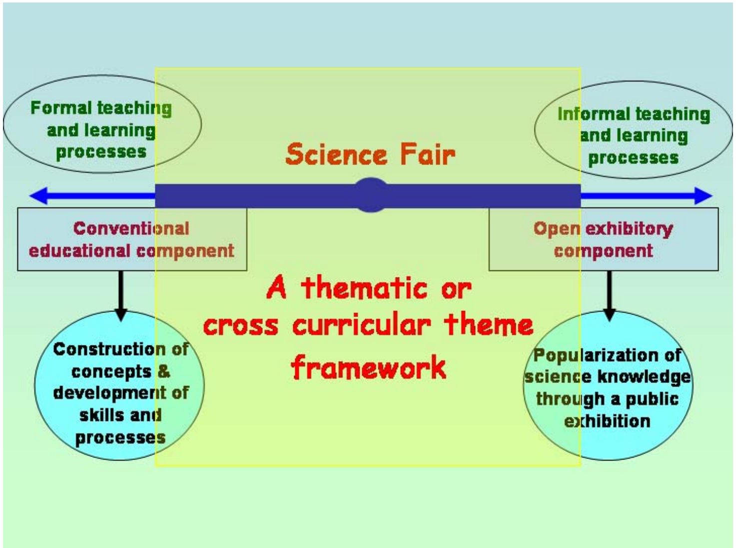


Fig. 1: *A science fair within an inter-thematic or cross curricular framework*

Furthermore, a “balanced” science fair appears to be occupying a considerable amount of middle space along a bipolar continuum with *formal teaching and learning processes* on the one end and *informal teaching and learning processes* on the other (see fig. 1). That is, informal processes interweave within formal and the other way round, in an attempt to bring together a *conventional educational component* with an *open exhibitory component* and consider how one can contribute to the other. In this sense, for a “balanced” science fair to occur, the construction of concepts and the development of skills and processes, seen as characteristics of a conventional education component, have to come closer to an idea of popularisation of science knowledge through an examination of every day instances and a public understanding of science and vice versa (cf. Fig. 1). This is not an easy balance to keep, neither for educators nor for learners. It appears to be insecure to slip closer to the conventional end of the continuum and miss all the joy and excitement of an investigative, discursive and inventive approach of the other end. Alternatively, if too much emphasis is put in the exhibitory end of the continuum, conceptualisation of phenomena and deeper understanding of processes is more likely to be underestimated or at least not equally treated, resulting a rather problematic approach about popularisation of science knowledge, based on unstable grounds.

2. A science fair on solar energy

The *science fair on solar energy* was organised by the 9th Primary school of Rethymno, Crete, Greece with 35 6th grade primary school children. The class was split in 3 big groups of 12 children with 6 pairs of children in each big group. Each of the three big groups had their own set of projects, which was solar heaters for the first group, solar cookers for the second and solar toys for the third (see Table 1). The children worked in pairs and developed projects and constructions which had to be functional and tested; therefore they had to develop certain techniques and deal with particular problems throughout the development of their projects.

Apart form the coordinator's supervision and assistance, children also received some help from two more teachers from the school staff, mainly during the morning sessions. Most of the supervision in the afternoon sessions for each pair of children was conducted with the aid of four 3rd year student-teachers from the local University Department. The children worked with the coordinator and the student teachers for their project, mainly in the afternoon sessions and it took about 3-5 meetings with each pair of children to complete their project.

The preparation of the science fair started in February 2003 and the final event was conducted in June 2003, in the school yard with more than 800 visitors, children and teachers from other local schools [*cf. URL:* < http://9dim-rethymn.reth.sch.gr/contents_gr/scilab/3rd_sci.fair.htm > *for a presentation of the science fair, available only in Greek for the moment, but with a lot of photographs*]. The science fair received some funding from an EU project on environmental science education, which helped us purchasing some of the materials needed in the science investigations and projects.

Photo 1: *The coordinator of the science fair introduces a group of visiting children and teachers to certain aspects of solar energy and their uses in every day life.*

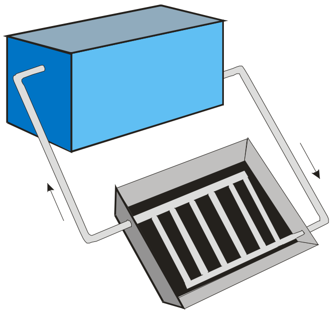
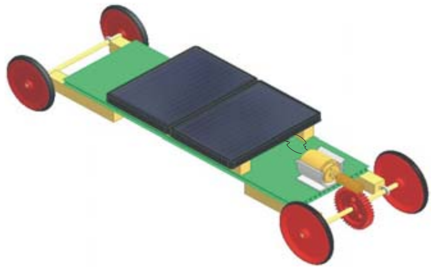
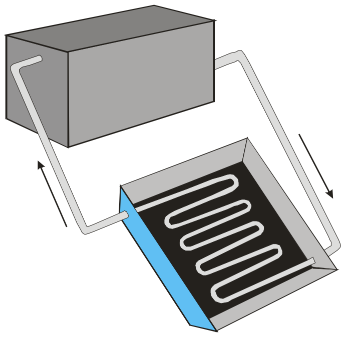
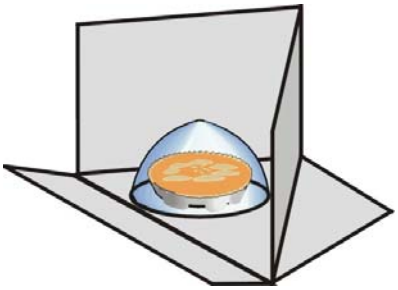
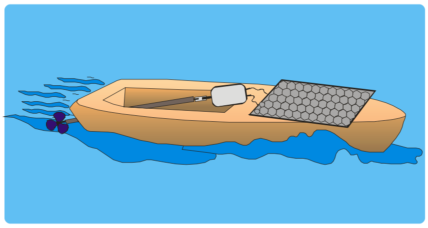
Photo 2: *Children had the opportunity to participate in same happenings and activities within the science fair, as in this case where they take part in solar car races.*

The science fair visitors, children and teachers, were briefly introduced in some aspects of solar energy (see Photo 1), which included:

- its origins in the Sun
- how it reaches the earth and what percentage can be of use
- a global solar energy map identifying parts of the earth were solar energy could be used more or less
- solar water heaters, their household uses and the thermosiphon effect
- solar cookers and their worldwide use in cooking food and pasteurizing water
- photovoltaic cells as solar energy converters to electrical energy and their use in households and industry
- solar and renewable energy policies and sustainable solutions for present and future

After that, the visitors moved on to a guided tour accompanied by a student teacher or a school teacher, whereas the science fair children explained to them how they had constructed their devices and the way they worked under the sun shine. Moreover, the visiting children had opportunities to participate in happenings and activities within the science fair, such as: solar boats and car races (see Photo 2, for example), feel the solar heated water from the solar heaters, taste solar cooked cakes and biscuits etc.

Table 1: Example drawings out of children's projects on solar energy

Solar water heaters	Solar cookers	Solar toys
		
		

3. Aspects of the interweaved teaching intervention

A 10-hour **teaching intervention** supported the science fair aiming to enhance children's conceptual understanding about the uses of solar energy in every day situations, mainly within three groups of applications: solar heaters, solar ovens and solar toys (toy cars and small boats moving with photovoltaic cells and motors). It dealt with issues like *"energy from the sun" "heat and light from the sun", "the greenhouse effect", "electricity from the sun"* (photovoltaic cells) *energy change* and *energy degradation* (cf. Global Solar Partners, 2000a & 2000b, Gurley & Larson, 1992; NEF, 1991). Moreover, social, environmental and ecological issues had been discussed in class, mainly concerning the energy crisis within a sustainable development framework, policies in the use and application of solar energy, cultural factors that encourage or resist the spread of solar energy applications and so on (cf. Narayanaswamy, 2001; Hayden, 2001).

The science experiments and investigations were mainly conducted in three phases, in reference to the three groups of constructions for the science fair, as has been reported above:

1. Experiments and investigations regarding **"solar water heating"**, where children initially studied water heating various sizes of aluminum containers left in the sun for some time. More precisely, they compared pairs of equally sized aluminum containers with the same amount of water in them, left in the sun for the same time, whereas one of them was painted black inside. A second experiment that they did was the "ice cube melting", where they placed ice cubes on the surface of black and white pieces of A4 cartons and they left them in the sun to melt, investigating which one would melt faster. Afterwards, they tried other colours of cartons and recorded their observations. Children had an idea that black things absorb more solar radiation, but with these investigations they found out how they can use this principle in solar water heating (cf. Tsagliotis, 2004). As the solar water heaters from children's projects were developing in the afternoon meetings, they were

brought to be tested in the morning sessions, out in the school yard, whereas proposals for their improvement were put forward after discussion with the children.

2. Experiments were conducted with **"green house models"** made out of equally sized boxes with top lids. Frames of carton around the sides of the boxes had been removed and replaced with transparent plastic film, Plexiglas, or usual glass. The children studied the performance of these "models of solar green houses" measuring the temperature increase inside them, when they were left in the sun for a period of time. The "greenhouse effect" was discussed in class and its main influences in global warming and climate change have been pointed out. Moreover, bridging analogies have been considered regarding the green house effect between the micro-level of our model devices and the macro-level of the planet. Thus, the *green house gasses* were analogically bridged with the *film or glass planes* of the green house models and the effect they have with the "trapping" of solar radiation and temperature increase was considered in each case. Similarly, aspects of the artificial creation of the green house effect inside a solar box cooker were discussed, in an attempt to obtain deeper understanding on how some the solar cookers work (cf. Tsagliotis 2004). Another group of experiments dealt with "hot boxes", which were actually cardboard boxes, covered with plastic film, Plexiglas, or glass on the top, with various colours of carton placed inside at the bottom and aluminium foil at the inner sides. They were left in the sun and their behaviour was studied. Nevertheless, the solar cookers developed within children's projects were also tested in whole class morning sessions.

3. Children also experimented with **"photovoltaic cells"** made out of amorphous and polycrystalline silicon. They began by measuring the rounds of a dot drawn on a circular piece of carton within a minute, when this piece of carton was attached to the shaft a motor operating with electrical energy coming from a solar cell. They experimented with the angles towards the sun in which they could turn the solar cell, in order to improve the performance of their motor. Many children thought that the solar cell worked much like the solar heater. This means that their idea, originating from more familiar experience with solar heaters, was that the solar cells produced electrical energy just because they were heated up in the sun (cf. Tsagliotis 2004). Thus, the idea was challenged by putting solar cells inside non transparent vessels and pots with lids, leaving them in the sun for some time. The temperature inside the containers with the solar cells increased, but electrical energy was never produced and the circular piece of carton attached to the shaft of the connected motor never moved. In this sense, they came to the conclusion that the solar cells were affected by the "sun's light" and they observed that they could stop their toys from moving, just by shading them. They further experimented with various colours of transparent films, but also with non transparent materials, which were put on top of the solar cells affecting their performance. Moreover, they used cartons with aluminium foil glued on them as reflectors around the solar cells and they observed that reflected light on the surface of the solar cells increased their performance for a little. They claimed that it was an idea taken from the reflectors of the solar cookers, which could have further applications (cf. Tsagliotis 2004). As their solar toy cars and boats were being constructed throughout the afternoon meetings, they were also tested in morning whole class sessions.

A nice thing about solar energy experiments and projects is that, for most cases, you just have to set them up and leave them in the sun shine (cf. DOE 1995; Daley, 1998). This provides time to proceed with a lesson or any other activity and then go and check on the devices over a school break or at the end of a teaching period and afterwards go back to some further discussion in class and so forth (cf. Centre for Alternative Technology, 1997; 1999; 2000a; 2001). Children appeared to be fascinated with the idea of checking their experiments and projects every now and then, recording their measurements and/or observations.

4. Solar water heaters

Solar water heaters appear to be a widespread technology in Greece, where roughly 30% of the solar collectors amongst E.U. countries are set up on the roofs of houses, hotels factories, etc. (cf. IDAE, 2000). Nearly half of those are established in Crete, which makes children very familiar with solar water heaters, increasing their interest to learn more about them.

There is a variety of solar water heaters designs to choose from (cf. CAT 2000b, Trimby 1999 for example), but we chose to construct the following:

- a "classic solar water heater" with flexible black tubes in horizontal and vertical arrays
- two "serpentine solar water heaters" with the flexible black tube arranged in an "S" shape
- a "spiral solar water heater" with the flexible black tube arranged in a circular form
- a "plastic bottles solar water heater" with the flexible black tube arranged in an "S" shape, passing through transparent, 1,5 litter soda bottles
- a "model solar water heater" with a spiral arrangement of a small plastic tube, where the water was gathered in a small container and circulated with a small water pump powered by 3 solar cells connected in a series.

Thus, six solar water heaters were constructed by a respective number of six pairs of children. For the frames of the solar collectors thick expanded polystyrene (DOW) was used, but also wood and cardboard. Flat, non toxic, black paint was used to cover the bottom parts of the collectors, whereas aluminum foil was used to cover the interior sides. Cardboard lids with glass were constructed to cover the top of the solar collectors. Flexible, black water tubes were mainly used inside the solar collectors and plastic cans were used as water containers or water tanks. In most cases theses water tanks were put inside polystyrene boxes, which were constructed according to their dimensions, in order to have better insulation.

Photo 3: *The testing of a "serpentine solar heater" constructed with flexible black tube, inside a collector box and a plastic can used as a water tank.*

Photo 4: *Final presentation of the "serpentine solar heater" in the science fair, with an improved incline for the serpentine loops, an improved water tank and some coloring.*

Nearly in all cases children had to resolve construction problems, which could even make their devices inefficient, as in the case of the "serpentine solar water heater". When we had initially constructed that solar water heater we were very pleased and left it in the sun for an hour or so in a morning session. Surprisingly enough, the water got hot inside the tubes and we could feel that, but we did not have the "thermosiphon effect". That is, the water did not circulate from the plastic tank inside the collector and back to the tank again, due to the density difference the cold water has compared to the hot (see Photo 3). It took us quite a while to find out that we had our water tank, the plastic can, tapped with its lid and that had some air trapped inside, the pressure of which created difficulties in water circulation. The problem was resolved as soon as we drilled a small hole in the lid of the can to equalise the pressures. One more thing we did to improve our model was to make the serpentine incline more steep avoiding the initial "curvy loops", which "created problems in the circulation of water" because it appeared to stay within these curved parts of the tube longer, trapped in a way (cf. Tsagliotis 2004). The improved model presented in the science fair was constructed accordingly in order to "ease the way of the hot water climbing up the tube" towards the water tank (see Photo 4, compared with Photo 3).

5. Solar cookers

There was a variety of designs for solar cookers to choose from (cf. Tsagliotis, in print), that is from *box solar cookers* (Kerr, 1991; Halacy & Halacy, 1992; Kofalk 1995, Radabaugh, 1998, Technology for Life, 1998), *open solar cookers with reflector panels* (Bernard, 1999, Tsagliotis, in print) or even *parabolic solar cookers* (Halacy & Halacy, 1997). We chose to construct three box solar cookers and three open solar cookers with reflector panels, whereas we avoided the construction of parabolic solar cookers, which are generally considered more technical and difficult (cf. Radabaugh, 1998; Tsagliotis, in print).

Photo 5: *Box solar cookers, as presented in the science fair, cooking biscuits and cakes for children and visitors to taste in temperatures ranging from 110 to 120 °C.*

Photo 6: *An open panel solar cooker, as presented in the science fair by this pair of children, cooking small round cake-rings for children and visitors to taste.*

The *box solar cookers* were constructed out of two boxes, one internal and one external, with insulation in between them, basically out of folded cardboard pieces (cf. Table 1). One of the solar box cookers had a top lid with a glass frame adjusted to its base, whereas the other two only had a plain glass frame laid atop their bases (see Photo 5). They all had a top reflector adjusted at the base of the cookers, which was set up against the sun accordingly to improve their performance (cf. Funk, 1997; Todd & Miller, 2001). The *open solar cookers with reflector panels* were constructed out of thick pieces of cardboard, which where set in place according to their design (cf. Table 1 and Photo 6). One was the classic Bernard (1999) design, whereas the other two had a more loose arrangement, with portable features (cf. Table 1, lower drawing in the solar cookers column).

The “green house effect” which is technically created inside the box solar cookers was discussed with children to a great extent as their projects were put to test in the morning sessions, before the science fair. Similarly, in the case of open panel solar cookers the green house effect is technically created inside a glass salad ball turned upside down in order to cover the cooking utensil with the food (pot, pan etc.) and “trap the heat inside”.

Nevertheless, quite a few environmental, social, ecological and economical issues regarding the use of solar cookers arose and they were discussed with children, but also put forward during the science fair. Such issues included the following:

- Solar cookers are mainly seen as “hot boxes” or “heat traps”, which can cook food for us, but also do other things which are important to people of the third world, and not only, such as pasteurization of physically contaminated water (Andreatta *et al.* 1994; Metcalf, 1994; 2002). Unsafe drinking water is one of the leading health challenges in the world today. Nearly 80% of all infectious diseases in the developing countries are transmitted through water (WHO). As a result, each year more than four million children die. It is not well known that water, when physically contaminated, can be pasteurized if heated in a temperature of 65 °C for a period of about 20 minutes, although the temperature-time relation may vary according to conditions (Ciochetti & Metcalf, 1984; Turdy, 1998).) This process can kill germs and disease-carrying organisms commonly transmitted in contaminated water. Such temperatures can easily be achieved in solar cookers, solving the problem of drinking water for many people. Unfortunately, though, pasteurization cannot remove chemical contamination, such as pesticides or industrial waste.
- Acute respiratory infections are the cause of death of millions of children in the world every year. The large majority of these casualties occur in the developing countries as a result of polluted indoor air due to cooking over open fires in houses without chimneys or ventilation. This problem could be greatly reduced by using solar cookers, which are smokeless over the process of heating and cooking the food. Furthermore, slow solar cooking at temperatures 100-150 ºC preserves several micronutrients better than conventional cookers do. Generally, solar cookers are very safe because we can avoid burning accidents.
- In the developing countries many people, mostly women and children, have to spend hours daily collecting firewood. This is a hard work and causes many injuries to people. Moreover, it contributes to the deforestation and desertification problems, the consequences of which affect human lives all over the world in present time (cf. Chidumayo, 1997). Solar cooking can reduce this time and effort significantly. Thus, women and children could use the time saved for education, leisure, social and communal activities. Of course, money can be saved to cover basic needs, since solar cookers need no fuel.

The most frequent question asked from visitors in the science fair was about the length of time that food needs in order to be cooked inside a solar cooker. Well, it depends on the food, the type of solar cooker and the weather conditions. If a solar box cooker is used, as a thumb rule it can be estimated that it will take twice as much time to cook food than the time it would take in a conventional oven. Perhaps we could see things in a different way and not worry that much about how fast the food can be cooked. Just get it in the solar box cooker early and go back at lunchtime to find a delicious meal ready, without any danger of being overcooked or burned.

6. Solar toys

The preparation and the experimental construction of *solar toy cars* and *boats* took some time and effort, since quite a few detailed problems had to be resolved and an appropriate combination of materials needed to be arranged and purchased (cf. CAT, 2001; NREL, 2001). Furthermore, the suitable kind of solar cells should be used for each construction to be functional (Komp, 2001). Thus, for example light and powerful photovoltaic cells were needed for the toy cars, whereas they were not necessary for the solar boats, which could move with smaller and heavier photovoltaic cells made out of amorphous silicone.

Another significant issue that arose was the "energy degradation", basically due to friction in axels, wheels, propellers, gears, pulleys and rubber bands. We had to "fight" frictional force in order to have more efficient solar toys on the one hand, but on the other we needed to have friction for the "O" ring rubber bands we used as tyres on the wheels of the toy cars (see Photo 7 and drawing in Table 1). In these terms, we had an interesting interplay with "energy change" from the photovoltaic cells to electrical energy, to kinetic energy and finally "energy degradation" to heat due to frictional forces in various parts of the toys. Children appeared to discern such characteristics of energy and they took a considerable effort to confront them and find solutions to a variety of construction problems (cf. Tsagliotis, 2004).

Photo 7: *Visitor children introduced to "solar toy cars" by one of the science fair children, explaining them how the photovoltaic cells can be considered as energy converters.*

Photo 8: *Children are watching and playing with the "solar boats" floating and moving around in a small swimming pool, which was constructed for the occasion.*

The solar motors, which were used for the toy cars, had to be of low friction and function with a voltage of 0,45-4 V with 2000-6000 rpm, suitable for photovoltaic cells, which could produce a potential up to 2 V. The chassis of the toy cars was made out of wood (balsa and pine), corrugated cardboard and Plexiglas. Their wheels were plastic pulleys with "O" rings around them, affixed on iron axels, which moved inside small pieces of plastic rigid tubes, glued at certain places on the chassis.

Another major problem in the construction of the solar toy cars was the transmission, which is actually the part that connects the motor shaft to the wheels or the axle. We experimented with gears, worm-screws and gears and with pulleys and rubber bands and found out that the latter was the most efficient of all for our toy cars. Thus, we fixed small iron pulleys at the shafts of the motors and 4-6 times bigger plastic pulleys to the axles of the wheels (see Photos 9 & 10). With this we achieved higher performance in terms or torque and speed for our solar toy cars, which made them more attractive, even for car races during the science fair. We constructed 7 or 8 different designs out of different materials and shapes, since more and more pairs of children wanted to construct their own solar toy as well. Thus, some children constructed solar toy cars and the rest constructed solar boats. We ended up with several solar toys at the science fair, which amused our visiting children and teachers since they could participate in happenings, play with them or even take a closer look to many of our solar toys.

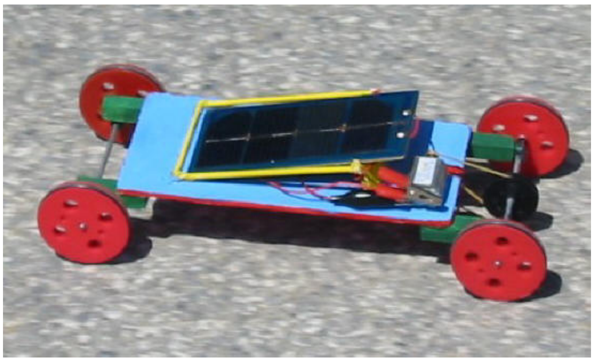


Photo 9: *A solar toy car … on the move during the science fair, on the asphalt surface of the school yard.*

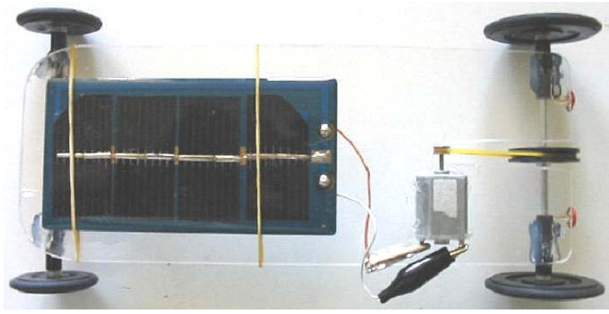


Photo 10: *A solar toy car made out of a Plexiglas chassis with a rubber band used for transmission, connecting the two pulleys between the shaft and the axle of the wheels.*

Similarly, children constructed solar boats out of expanded polystyrene, balsa wood, but also from scrap materials like used plastic bottles (see Photo 11). They also constructed fishing boats moving with propellers or even a couple of “river boats”, which were moving with paddle-wheels made out of gears with attached plastic fins (see Photo 12).

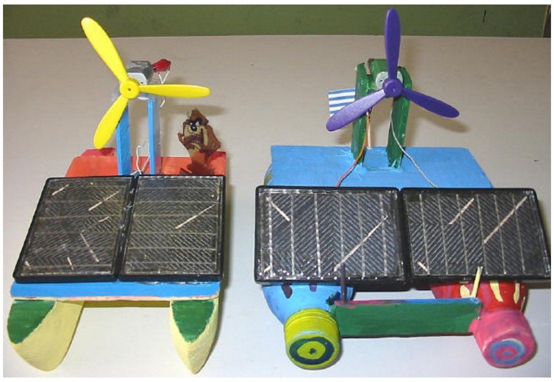


Photo 11: *Two solar catamaran boats. Their floaters are made out of expanded polystyrene (left) or used plastic bottles (right) and they both moved with a helix.*

Photo 12: *Two solar “river boats” with paddle-wheels made out of gears with attached plastic fins cut out of plastic bottles.*

For our solar boats to be effective we had to give them hydrodynamic shapes in order to have less energy degradation or “not to have a lot of energy put out of use”, that is turned into heat due to frictional forces between the surfaces of the boats and the water (cf. Tsagliotis, 2004). Thus, children had to sandpaper the floaters of their boats to the shapes seen above or find materials of relative shape (see Photos 8, 11 & 12). This became a fascinating task, which ended up in contests for faster boats, according to their category of course.

7. Overview and discussion

The thematic approach to the science fair, as it has been briefly described above, appears to have captured children’s interest and engaged them in an effort to create their own functional models of solar energy applications. Perhaps the essence and educational merit of the whole endeavor is this particular intentional task, where children are actively involved in a project, which they consider to be their own, and they purposefully feel highly committed to complete it as their personal creation and contribution. This commitment lies at the hard core of a thematic science fair project, which appears to be triggering all the other conceptual, discursive and inventive features to be constituted into a broader framework of “science knowledge in action” with “hands on” activities based on every day situations.

In other words, children actually built up their solar heaters, cookers and toys and they practiced "science in action", as they got involved in the construction processes and dealt with their functionality and refinement problems, as they were put into test during the development of their projects. This process has always been a purposeful goal in the way of "doing science for something", which appears to increase interest and the emotional factors of "having fun with science" and with "hands on" activities, within a framework of particular applications of everyday life.

Despite the critique and predictions of skeptics, that solar energy will never run the world, at least not within a rosy solar future (cf. Hayden, 2001), the children of the science fair, and perhaps some of the visitors, became highly sensitized about available solar energy applications, saw them work in practice and realized some of their limitations and their questionable or disputable potential.

References

Andreatta, D., Yegian, D.T., Connelly, L., & Metcalf, R.H. (1994) Recent advances in devices for the heat pasteurization of drinking water in the developing world. Paper presented at the *29th Intersociety Energy Conversion Engineering Conference*, American Institute of Aeronautics and Astrophysics.

Beane, J. (1997) *Curriculum integration: Designing the core of democratic education*, New York: Teacher College Press.

Bernard, R. (1999) *La Cuisson Solaire Facile*, Editions Jouvence.

Centre for Alternative Technology (CAT) (1997) *Teacher's Guide to Renewable Energy Projects: Solar Heating*, Devon: Southgate Publishers Ltd.

Centre for Alternative Technology (CAT) (1999) *Teaching about Energy: Practical Activities for 7-11 year olds*, Devon: Southgate Publishers Ltd.

Centre for Alternative Technology (CAT) (2000a) *A pupil's Guide to Solar Power*, Devon: Southgate Publishers Ltd.

Centre for Alternative Technology (CAT) (2000b) *Tapping the sun: A guide to water solar heating*, Devon: Southgate Publishers Ltd.

Centre for Alternative Technology (CAT) (2001) *Teacher's Guide to Solar Electricity Projects*, Devon: Southgate Publishers Ltd.

Chidumayo, E.N. (1997) Woodfuel and Deforestation in Southern Africa – a misconceived association, *Renewable Energy for Development*, Vol. 10 (2). URL: < http://www.sei.se/red/red9707c.html >.

Ciochetti, D.A. & Metcalf. R.H. (1984) Pasteurization of naturally contaminated water with solar energy, *Applied and Environmental Microbiology*, Vol. 47, pp. 223-228.

Daley, M. (1998). *Amazing sun fun activities,* New York: McGraw-Hill.

Department of Energy (DOE) (1995). *Solar Energy Science Projects*, USA. Available at URL: < http://www.eia.doe.gov/energy >.

Fredericks, A. D. & Asimov, I. (1990). *The complete science fair handbook*. Illinois: Good Year Books.

Funk, P.A. (1997) Evaluating the International Standard Procedure for Testing Solar Cookers and Reporting Performance. Paper presented at the *"3rd World Conference on Solar Cooking"*, Avinashilingam University, Coimbatore, India, 6-10 January. URL: < http://web.nmsu.edu/~pfunk/std.pdf >.

Global Solar Partners (2000a) *Energy for the 21st Century: Solar exchange Unit*. Published by the *Association for Science Education*, Hatfield: U.K. URL: < http://www.solarpartners.org/plans.html >.

Global Solar Partners (2000b) *Energy for the 21st Century: Study Notes and Activities (Ages 11-16)*. Published by the *Association for Science Education*, Hatfield: U.K. URL: < http://www.solarpartners.org/plans.html >.

Gurley, H. & Larson, B. (1992). *Sunlight Works: Solar Science Educational Activities for Children*, Arizona: SunLight Works.

Halacy, B. & Halacy, D. (1992). *Cooking with the sun: How to build and use solar cookers*, Lafayette: Morning Sun Press.

Halacy, B. & Halacy, D. (1997). *Solar StoveTop Cooker*, Lafayette: Morning Sun Press.

Hayden, H.C. (2001) *The Solar Fraud: Why solar energy won't run the world*, Vales Lake Publishing, LCC.

Institute for the Diversification and Saving of Energy (IDEA) (2000) *Renewable Energy for Europe: Campaign for Take-Off*, European Commission, printed in Spain. URL: < www.idae.es >.

Kerr, B.P. (1991) *The expanding world of solar box cookers*. ISBN: 096326740X. URL: < http://www.accessone.com/~sbcn/kerr.htm >.

Kofalk, H. (1995) *Solar Cooking*, Summertown: Book Publishing Company.

Komp, R. (2001) (3rd Edition.) *Practical Photovoltaics: Electricity from Solar Cells*, Michingan: AATEC publications.

Metcalf, R.H. (1994) Recent advances in solar water pasteurization, *Solar Box Journal*, No. 16. Available at URL: < http://solarcooking.org/metcalf.htm >.

Metcalf, R.H. (2002) The science of safe water, *Solar Cooker Review*, Vol. 8(3). Available at URL: < http://solarcooking.org/newsletters/scrnov02.htm#water >.

Narayanaswamy, S. (2001). *Making the Most of Sunshine: A Handbook of Solar Energy for the Common Man*, New Delhi: Vikas.

National Energy Foundation (NEF) (1991) *Science projects in renewable energy and energy efficiency*, Salt Lake City: USA.

National Renewable Energy Laboratory (NREL) (2001) So ... *You Want to Build a Model Solar Car*. Available at URL: < http://www.nrel.gov/education/student/natjss.html >.

Radabaugh, J. (1998). *Heaven's Flame: A Guide to Solar Cookers*, Ashland: Home Power Publishing.

Technology for Life (eds.) (1998). *Something new under the sun: Manual for solar box cookers - How to build and use them*, Helsinki, Finland. URL: < http://www.kaapeli.fi/~tep/man/manual.html >.

Todd, J.J. & Miller, S. (2001) Performance Testing of Cardboard Solar Box Cookers. Paper presented at the *"Women Leaders on Uptake of Renewable Energy Technology Seminar"*, Murdoch University, Perth, Western Australia, 27 June-4 July. URL: < http://acre.murdoch.edu.au/unep/frameset.htm >.

Trimby, P. (1999) *Solar Water Heating: A DIY Guide*, Devon: Southgate Publishers Ltd.

Trudy, R. (1998) Sun and water: an overview of solar water treatment devices, *Journal of Environmental Health*, Vol. 60(10), pp. 30-33. URL: < http://solarcooking.org/sunandwater.htm >.

Tsagliotis, N. (2004) Conceptual change in the teaching and learning of solar energy with 6th grade primary school children in Greece. Paper presented in the "*4th EARLI European Symposium on Conceptual Change: Philosophical, Historical, Psychological and Educational Approaches*", Delphi, Greece, May 19-22.

Tsagliotis, N. (in print) *Delightful Solar Cooking: A tour in the world of solar cookers*, Rethymno: Typospoudi Publications (in Greek).

Van Cleave, J. (2000) *Guide to more of the Best Science Fair Projects*. New York: John Wiley & Sons, Inc.