On high school physics and student assistance in introducing solar cooking to Bedouin

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Abstract

The functioning of a solar cooker is an ideal subject for teaching fundamental aspects of physics at any level of education, but is especially suitable in high school (grades 10 to 11) for physics students. Concepts of radiation, its spectral distribution, transmission through glass, the laws of reflection and heat transfer all play an essential role in the performance of a solar cooker. In an environment where a high school and local population, still mainly relying on fossil fuel for cooking, are physically close to each other, it opens the opportunity for combining teaching physics and introducing solar cooking to the Bedouin via the high school students. In this case an additional benefit was obtained by bringing the students into contact with the Bedouin children of very different ethnicity and background.

The rationale for this work was therefore twofold: (1) to teach physics to high school students in a particularly interesting fashion by introducing the project of solar cooking, complete with designing, building and testing a variety of cookers, and (2) to interest the local population, Bedouin who live nearby in simple conditions, in solar cooking. The first part was achieved via a combination of in-class lectures, solar cooker designs and their constructions with very simple and low-cost materials, and finally experimental evaluation of the cookers. The second part was realized by linking up with the nearby elementary Bedouin school, first interesting the teachers and then having a team of high school students visiting the Bedouin school and demonstrating two types of cookers. The Bedouin students, who were fascinated by the cookers, built later on simple solar panel cookers and tested them under the guidance of their teachers and the high school students.

The first goal of teaching physics could certainly be considered successful; the students' achievements and feedback were very positive. Regarding the second aim, though Bedouin teachers and students were enthusiastic about the demonstrations and building the panel cookers, one could not observe a continuation of the initiative and it is unclear if there was any follow up or continued interest in studying or adopting solar cooking by the Bedouin community.

1. Introduction

At the interfaces between societies that we would consider modern on one hand and traditional on the other one can sometimes find opportunities for introducing solar cookers. While it is certainly desirable to introduce solar cooking to modern society, it is a difficult task for reasons all too well understood: dense housing limits access to the sun, and beyond this, work habits of being out of the home for five days a week substantially deter the use of solar cookers. Traditional societies with their lower standard of living, usually live in open spaces with access to solar radiation, can, in principle at least, make use of solar cooking, reducing the dependency on fossil fuels for cooking. Typically, there is a social gap between these societies, so much so that there is hardly any contact between them. This is certainly the case with regard to the Bedouin communities of the Negev Highlands, a mainly arid to semi-arid region in the southern part of Israel. The Bedouin living in this area belong to the Azazme' tribe and are still mostly using wood for cooking. Most of the wood is gathered from the immediate environment. Decreasing the amount of firewood used for cooking is highly important in drylands, as the resilience of the ecological system is very low (Levin and Ben-Dor, 2004) and can lead to a non-reversal process of desertification (Yizhaq et al., 2007). In supplying the required energy for food preparation, solar cookers can fully or partially replace firewood in many developing and sunny areas (Schwarzer and da Silva, 2003). In addition, time not spent in scavenging for firewood can be gainfully used, mostly by women, in other activities such as education or home business (Wilson and Green, 2000; Wenzel, 2007).

There have been many reports on attempting introducing solar cooking, such as described by (Wilson and Green, 2000), to mention just one case, with more or less success. Here we suggest a different approach. It is based on a combination of physics education of students from a modern society and interaction of these students with Bedouin students. The idea is to bring the information and practice of solar cooking to Bedouins via the children, with the participation of their teachers. It also builds on the natural curiosity of young students: a solar cooker is a wonderful device by means of which one can study many subjects: such as material properties (transparency, absorption, reflection, insulation, etc.), geometry, like how to build a 3-dimensional parabola from flat surfaces, the properties of light, or the physics of heat transfer. The material required to construct cookers for experimenting and demonstration is low-cost and any child from the age of 10 up can learn how to make a cooker with some guidance by a teacher. Furthermore, simple experiments can be performed such as heat up tests, stagnation temperature measurements, depending on the availability of modest-cost sensors. Thus other skills can be learned using the cookers, such as producing plans, performing and analyzing experiments, and presenting and interpreting the results.

We report on the experience the authors had over a three-year period during which high school students were exposed to theory (physics related to solar cookers), geometry (design of box cookers, geometry of spherical or paraboloidal cookers), and construction, testing and experimenting with the cookers. The same students were then invited to share their experience with the Bedouin children together with their teachers, including construction of panel cookers. It is believed that similar interfaces between societies may well exist in other parts of the world and could provide one of the available avenues to make solar cookers known to a wider population, while, at least in our case, there was the additional benefit of having the two highly separate societies interacting and finding some common interest.

2. Physics education

The following subjects were treated in-class prior to the design, construction and testing of the solar cookers:

- Solar radiation, its spectrum, earth-sun geometry, scattering in the atmosphere – the explanation for the diffuse radiation. Cosinus effect on a surface not perpendicular to the radiation;
- Transmission of radiation through transparent material as a function of wave length. The Fresnel reflection losses of about 4% per air/dielectric interface. The opacity of the material to longwave radiation; Bouger's (or Beer-Lambert's) law of absorption in transparent media;
- Reflection of radiation from specular surfaces; flat mirrors; concentrating mirrors: spherical and paraboloidal mirrors and their focusing capabilities;
- Heat transfer: thermal radiation, convection and conduction; material properties – insulating materials;

The lessons comprised weekly 1.5 hour lectures to high school students in the 10^{th} grade with physics and mathematics orientation. The students then developed designs based on these lectures and built their own models. In one year two groups formed: one designed a paraboloidal concentrator, the second a spherical concentrator. While the former provides better focusing capabilities, the latter has the advantage that less frequent tracking of the sun is necessary. The designs were presented by the students in class (Fig. 1) and discussed by teachers and students.

The curved mirrors where produced from polycarbonate sheeting (4 mm hollow material) and household type aluminum foil glued onto the sheets. The curved shapes were produced by 'leaves' the geometry of which had to be carefully determined (Fig. 2), so that upon combining them with duct or masking tape, a proper, though approximate, paraboloid or sphere would emerge (Figs. 3 and 4). In a second year the students were asked to produce box cookers from simple materials such as cardboard.

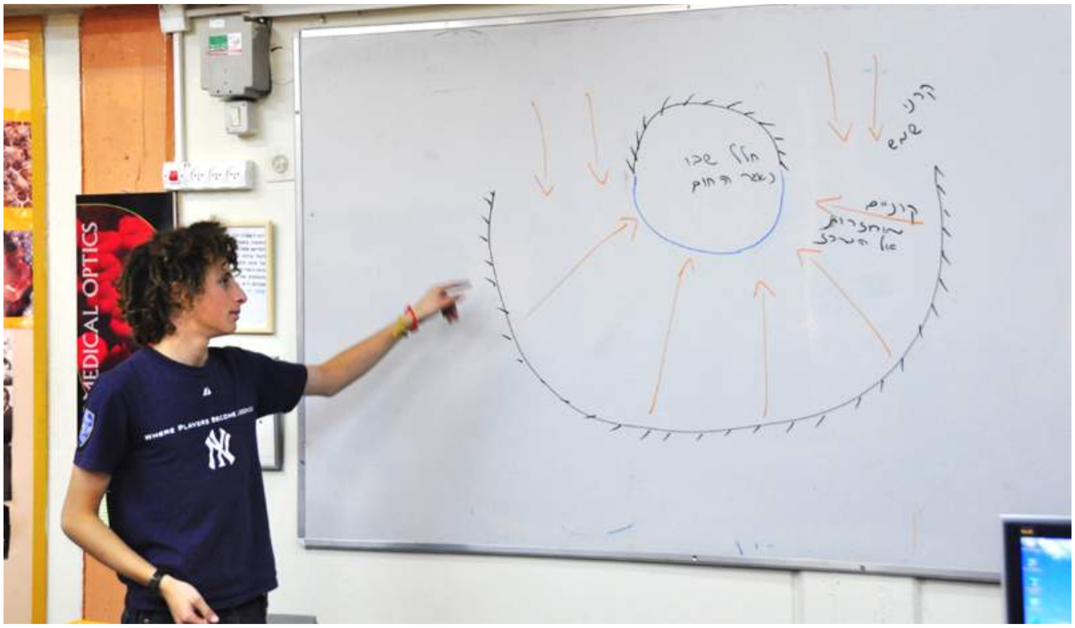

Fig. 1. Student presentation of a suggested design.

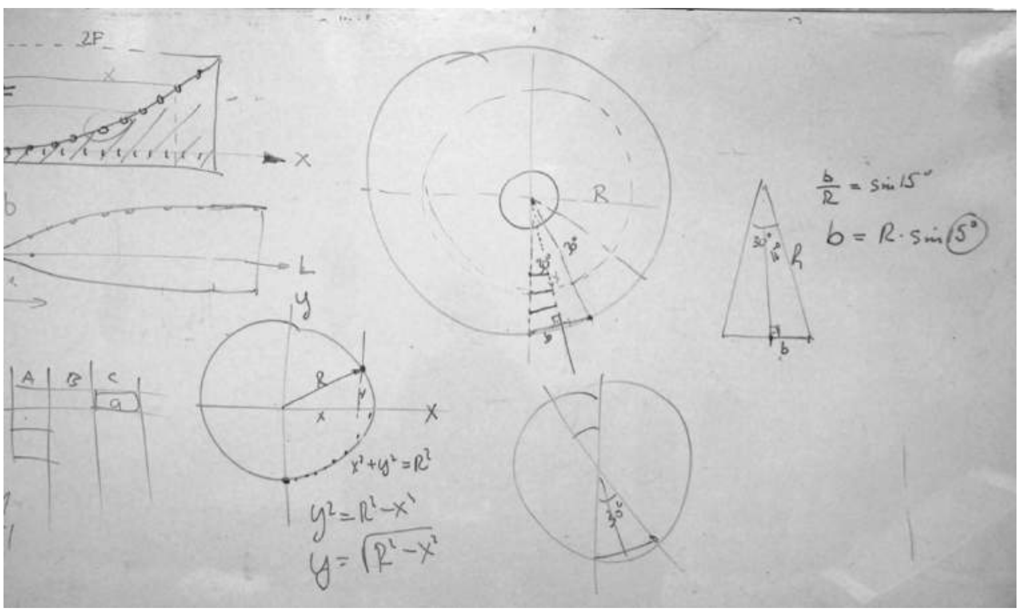

Fig. 2. Geometry for designing ‘leaves’ of the curved mirrors.

Fig. 3. Production of the individual leaves.

Fig. 4. The assembled concentrators; left the hemisphere – right a paraboloid.

3. Experimentation

Part of the education was to expose the students to measurement techniques. Stagnation tests were performed for the various cookers so that the students could compare the performances of their designs (Fig. 5).

Similar tests were performed for the spherical and paraboloidal cookers, though rather than stagnation tests, heat up tests were performed with the intention to estimate the efficiency.

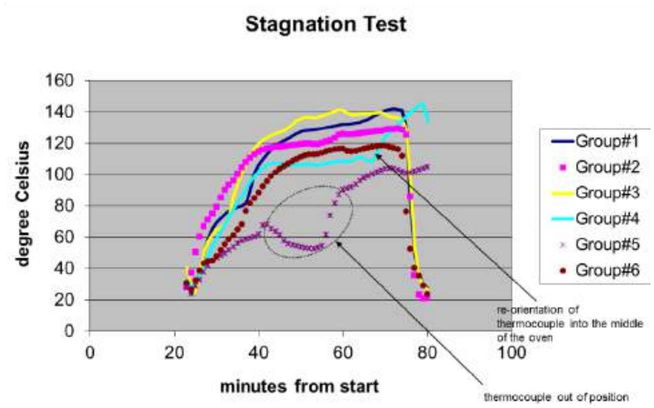

Fig. 5. Stagnation tests for box cookers (left) and test results for the 6 groups (right). Ambient temperature during this time was 20 C.

4. Visits to the Bedouin school and introduction of panel cookers

The Environmental high-school where the 10th graders were participating in the project is located some 7 km from the Bedouin school (1st to 8th grades) which serves the Bedouin community of the Azazme' tribe. Communications with the teachers and the school's principal there revealed genuine interest in the collaboration between the two schools and in solar cooking as a tool for teaching students at various levels. In one of the visits, the high school students, together with their teachers, brought their recently produced solar cooker (the parabolic dish, which turned out to be the more efficient cooker) as well as a box cooker made from recycled materials, for a demonstration (Figs. 6 and 7b). Naturally, interest was high, especially as hot tea was prepared with the cooker, and students could feel the heat near the focus of the dish.

As box cookers and concentrating cookers are relatively involved in terms of the time it takes to make them, it was decided to introduce solar panel cookers, based on the geometry of the ‘cookit’ (Solar Cookers International). The material was well prepared, helped by a modest financial support of the Fund for Innovation in Teaching [http://www.keren-yozmot.org.il/en/]. The shapes of the panel cooker (individual pieces of 3mm thick plywood, Fig. 7c) were cut from large plates by a carpenter so that the students would only have to glue aluminum foil, using a brush and water based white glue, after which the pieces were put together with duct tape, permitting the panel cookers to be folded. The panel cookers were then used to bake potatoes and cook vegetables to the amazement of the children. Simple heat up experiments were also performed and temperatures were measured (Fig. 8).

Fig. 6. Demonstration of the paraboloidal dish at the Bedouin school Ein Avdat.

Fig.7. Tea from the sun (a) and a box cooker from recycled material (b). Preparation for building a panel cooker (c).

Fig. 8. (a) A group of three girls and their science teacher with the finished solar cooker; (b) Employing a digital thermometer to show the Bedouin students the temperature that can be reached in the panel cooker; (c) a student measuring air temperature inside a plastic baking pan (suitable for high temperatures) in the panel cooker.

5. Discussion and conclusion

As many researchers have documented, the acceptance of solar cookers by a target population is typically a tedious and slow process (Blum, 1998; Quadir, 1995; Eberhard, 1984; Bergler et. al., 1999) and has to be carefully considered, with emphasis on social aspects. In the present work, a novel approach was tried in that local high school students were involved with first an in-depth learning of the functioning of solar cookers, from the point of view of physics. In a second step, the same high school students were allowed to interact with children from the Bedouin community, and, together with their teachers, introduced the idea of solar cooking to the Bedouin children, including a workshop in which the children built their own panel cooker which they took home. The hope was that the children, bringing home the constructed solar cookers, would perhaps develop the interest of their parents.

While parts of the project can be considered successful, such as the physics education of the high school students and the exposure of the Bedouin students to solar cooking, the hoped-for effect of introducing solar cooking to the Bedouin families and creating an interest in continuing to develop and build cookers themselves, be it panel cookers or box cookers, appeared to be lacking. Still, it is believed that the suggested approach in involving two schools from diverse backgrounds may have a positive influence on igniting interest in solar cooking in many places where rural populations are living side by side with a more affluent society.

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References

Bergler, H., Biermann, E., Grupp, M., Owen-Jones, M. and Palmer, R., 1999. Moving ahead with solar cookers: acceptance and introduction to the market. *Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Eschborn. URL http://www. gtz. de/de/dokumente/en-solarcooker. pdf.[10/08/2011]*.

Blum, B. L., editor, *Spreading Solar Cooking*, Solar Cookers International field guide, 3rd ed. 1998.

Eberhard, A. A. 1984, Dissemination of Solar Ovens in Lesotho: Problems and Lessons. *Proceedings of the Eighth Biennial Congress of the International Solar Energy Society*. New York: Pergamon Press.

Levin, N. and Ben-Dor, E. 2004. Monitoring sand dune stabilization along the coastal dunes of Ashdod-Nizanim, Israel, 1945-1999. J*ournal of Arid Environments*, 58: 335-355.

Schwarzer, K. and da Silva, M. E. V., 2003. Solar cooking with or without heat storage for families and institutions. *Solar energy*, 75: 35-41.

Solar Cookers International, 1994, http://solarcooking.wikia.com/wiki/CooKit

Wentzel, Marlett and Anastassios Pouris, "The development impact of solar cookers: A review of solar cooking impact research in South Africa," *Energy Policy* 35 (2007) 1909–1919.

Wilson, Merridy and J Maryann Green, "The feasibility of introducing solar ovens to rural women in Maphephethe," *Journal of Family Ecology and Consumer Sciences*, Vol 28, 2000

Quadir, S. A., S. S. Mathur, et al. (1995). "Barriers to dissemination of renewable energy technologies for cooking." *Energy Conversion and Management* 36(12): 1129-1132.

Yizahq, H., Ashkenazy, Y. and Tsoar, H. 2007. Why do active and stabilized dunes coexist under the same climatic conditions? *Physical Review Letters* 98: 188001.