Outreach Activity on Energy and Thermoelectrics

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Background

The activities below were developed in summer 2009 and 2010 during 2-day summer workshops for science teachers from regional high schools, as part of the NSF-funded SPIRIT program at UC Riverside (ENG# 0836020, Success Partnerships for Increasing Recruitment into Technology). They are also part of the outreach efforts in my NSF CAREER proposal, from which this document is a near-verbatim excerpt. In the future I hope to refine it with help from a visiting high school teacher, to provide more detailed guidance and structured worksheets specifically targeted towards a high school classroom. In the meantime I am posting these rough notes.

Energy & Thermoelectricity (Fig. 1)

This demonstration shows the equivalence of heat, electrical work, and shaft power. Besides the SPIRIT workshops (Fig. 1(b)), this demonstration is also used in the opening lecture of the PI's junior-level thermodynamics course (ME100A).

This workshop follows one of the standard lesson models for K-12 science education, the "5E" model: Engage, Explore, Explain, Elaborate and Evaluate [1,2]. For the initial Engage and Explore phases, we intentionally refrain from telling the students anything about the thermoelectric (TE) effect. Instead we introduce a TE module as a mysterious gadget with 2 wires and no moving parts, but unknown function. We then proceed through a process of joint discovery, eliciting and testing various hypotheses from the students. This gives students a taste of the excitement of scientific discovery. A typical workshop proceeds as follows (Fig. 1):

(a) Students speculate about what will happen when the TE leads are connected to a battery pack (e.g., "nothing", "gets hot", or "hums"). After connecting the leads, students listen and briefly touch the top of the module, confirming the heating, which is then further emphasized by boiling a small puddle of water.

(b) What if we reverse the leads? Many students expect more heating, but a few venture that the device might “run backwards and get cold.” Remarkably, when the leads are connected, the liquid indeed freezes into ice. Due to subcooling, the sudden flashover from liquid to solid is particularly dramatic.

(c) We also investigate the backside of the TE module -- do both faces get cold simultaneously, or is it cold/hot?

(d) The flows of work and heat in (a)-(c) are sketched on a board, introducing the control volume concept. Is there another way to run this "in reverse"? Some students speculate: “if heat goes *in*, maybe somehow we can get electricity *out*...?” For a compelling visual the TE device is mounted upside down and heated by a small birthday candle. This TE device really can do work, powering LEDs or a motor.

We conclude the workshop discussing practical applications, and explain that one of the major challenges is their low efficiency which is largely a materials issue that is being intensively researched, allowing the PI to speak briefly about his own work. We have budgeted the modest funds necessary to build at least 4 of these TE demonstration rigs every year (cost ~$50/rig), with the intention that each workshop will conclude with a working TE rig to remain permanently in that high school classroom for further use and study.

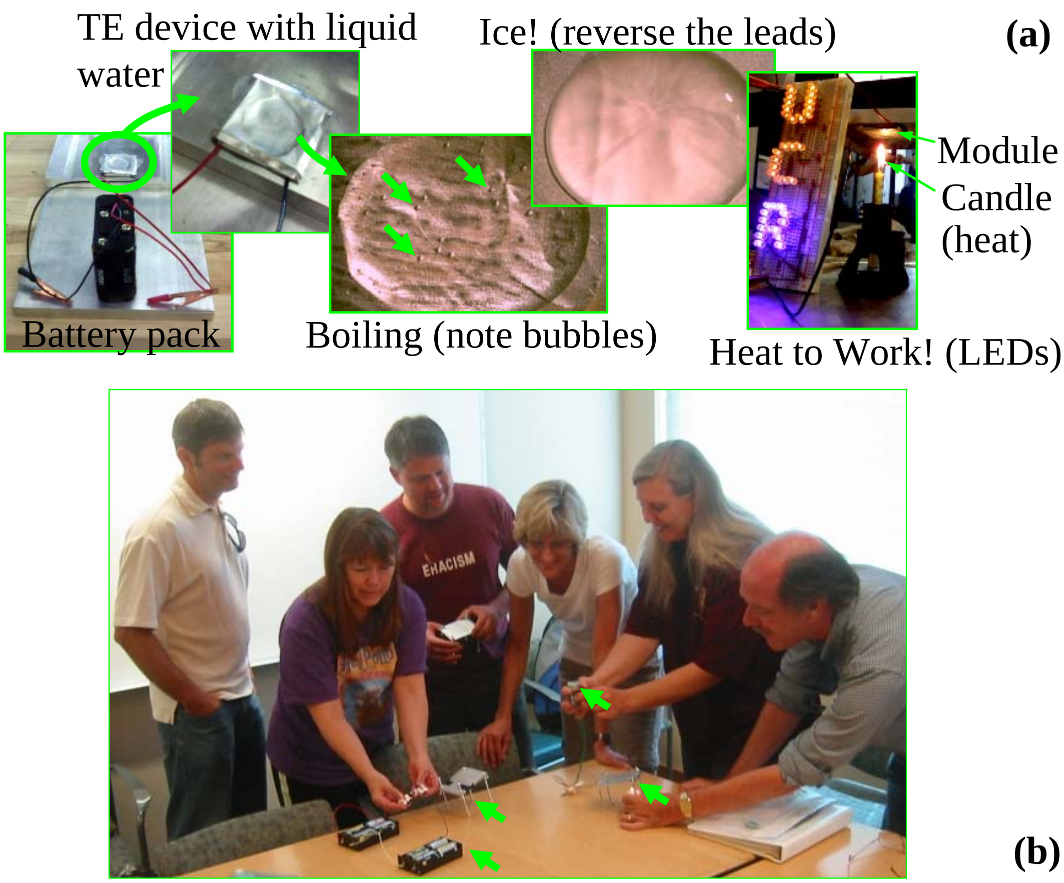

Fig. 1. Thermoelectricity workshop. (a) Demonstration of the equivalence of a heat pump (boiling), a refrigerator (freezing), and a heat engine (powering LEDs), simply by changing the connections to a basic TE device. (b) Example of similar TE demonstration rigs made with, and given to, regional high-school teachers as part of the NSF-funded SPIRIT program at UCR.

Parts Used

For a list of key parts, see spreadsheet *TE_part_list_brief.xls*. Some of the most important / non-obvious were the TE module (Tellurex G1-34-0315), a low-voltage DC motor (Sundance Solar 700-60062-00), and 8 D (or AA) cells in series.

<u>*References*</u>

1. R. W. Bybee, J. A. Taylor, A. Gardner, P. Van Scotter, J. C. Powell, A. Westbrook, and N. Landes, *The BSCS 5E Instructional Model: Origins, Effectiveness, and Applications* (BSCS (Biological Sciences Curriculum Study), 2006).
2. A. Eisenkraft, "Expanding the 5E model". *The Science Teacher* **70**, 56 (2003).