Physics Hands-On Research School

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A winter school for young scientists from developing countries focused on laboratory table-top research.

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Following in the grand tradition of the summer schools established at Les Houches and Varenna in the early 1950s, and the many summer and winter schools in theoretical physics that followed the Les Houches/Varenna model (Box 1), 45 young scientists gathered for a two-week school in Gandhinagar, India, on 6 January 2008. But the school in India was different – the focus was not on theoretical physics but on hands-on laboratory research and complementary mathematical modeling. The participants came from developing countries where resources are limited and, as a consequence, laboratories equipped for cutting edge research are rare. Many participants shared the common perception that modern science necessarily involves large expensive instrumentation and large teams of scientists. In contrast, the nine leaders of the **Hands-On Research in Complex Systems** school were all senior scientists who had demonstrated through their research and publications in journals such as *Physical Review Letters, Science,* and *Nature* that table-top experiments can address problems at the frontiers of science.

Participants in the Hands-On school developed an understanding of physical phenomena by making measurements, varying parameters, analyzing data, and drawing their own conclusions about their observations (figure 1). Each laboratory session had only five or six participants and was led by a senior physicist and an assistant (typically a graduate student). The participants came from 21 countries: Brazil, Cameroon, China, Columbia, Egypt, India, Iran, Lebanon, Malaysia, Mexico, Morocco, Nepal, Nigeria, Philippines, South Africa, Sri Lanka, Trinidad, Tunisia, Turkey, Viet Nam, and the West Bank. Nearly three-fourths had PhDs, and the rest were graduate students; 27% were women. Although a few were experimentalists, most were theorists with limited laboratory experience. The background and knowledge of the participants varied considerably, but curiosity and a willingness to learn as well as teach kept the sessions lively and engaging for faculty and participants alike.

The idea for a hands-on research school developed in 2005 from discussions among the first three authors concerning the appropriateness of table-top physics for instruction and research in developing countries. The immediate challenge in planning a school was to find financial support and a location with the needed laboratory space, computers, lecture hall, etc. By luck one of us (Rajarshi Roy) had a conversation with Abhijit Sen of the Institute of Plasma Research (Gandhinagar, India) while waiting for flights following a conference in Mexico. Sen suggested the Institute for Plasma Research might host a hands-on school and provide local support for participants and faculty.

Box 1. The origin of summer schools in theoretical physics

In 1951 the *Les Houches Summer School of Theoretical Physics* was founded to provide young physicists in Europe the opportunity to learn directly from the authors of exciting post-war developments in theoretical physics. [See "Theoretical Physics in the Alps", *Physics Today*, Vol. 4, No. 12, pp. 22-23, December, 1951.] The 20 participants in this summer school were required to stay for the full eight weeks, which was not a hardship given the spectacular beauty of the remote setting. Lectures were given six mornings each week, and the lecturers were available for afternoon discussions. Lecturers in the first school included Walter Kohn, Wolfgang Pauli, Emilio Segre, and Victor Weisskopf. Les Houches summer schools in the past half century have been spectacularly successful in training physicists – 26 of the participants have subsequently received Nobel prizes (http://w3houches.ujf-grenoble.fr/index-en.html).

In 1953 an Italian *International School of Physics "Enrico Fermi"* was founded on the Les Houches model, and in the initial years the Les Houches and Fermi school programs were closely coordinated. The famous Fermi schools are now held in three two-week long courses each summer (www.sif.it).

In 1958 the Scientific Advisor of NATO, Norman Ramsey, announced that NATO would support summer institutes, citing the highly successful summer Les Houches and Fermi schools as examples of such activities. The NATO Advanced Study Institutes have grown to span a wide range of topics in science, engineering, agriculture, and public policy.

Many summer and winter schools in physics are now held each year throughout the world. Some are held at the *Abdus Salam International Centre for Theoretical Physics* (ICTP), which was established in 1964 in Trieste, Italy, to provide opportunities for scientists from developing countries to attend schools and workshops together with leading scientists from developed countries. The Centre's leading administrative agency is the United Nations Educational, Scientific, and Cultural Organization (UNESCO). In 2006, more than 6000 scientists from 126 countries visited ICTP; about the same number of scientists came from developing and developed countries. Thus ICTP has become one of the world's most fruitful examples of international scientific cooperation.

We then contacted K. R. Sreenivasan, director of the Abdus Salam International Centre for Theoretical Physics (ICTP), who encouraged us to submit a proposal to that Centre. ICTP committed full administrative support for three Hands-On Research schools, to be held in successive years in India, Latin America, and Africa. ICTP also committed funds for participant travel support. A grant for faculty travel to the school in India was then obtained from the Indo-U.S. Science and Technology Forum, and further support was awarded by the University of Maryland. An announcement of the school in India was posted on the ICTP website in the spring 2007, and by the 1 October closing date we had received about 250 applications from 42 developing countries.

We recruited five more faculty with known pedagogical skills and a commitment to the mission and spirit of the school. The nine senior faculty and their assistants (Box 2) began preparing laboratory experiments and demonstrations during the year preceding the school. They developed experiments using inexpensive equipment such as webcams and USB computer interfaces that cost about $100. The staff at the Institute for Plasma Research set up experimental research areas and a room with computers for the mathematical modeling sessions. They also filled requests from the hands-on session leaders for computers, power supplies, oscilloscopes,

Box 2. Hands-On Research session topics and the leaders (and assistants)

Brownian motion, microscopy, and complex fluids	Eric Weeks (Kazem Edmond)
Boolean networks of electronic gates	Daniel Lathrop (Chirag Kalelkar)
Mathematical modeling	Brian Storey (David Boy, Nathan Karst, and Norbert Marwan)
Metronome synchronization, bouncing drops, and thermal convection	Michael Schatz
Vibrated granular materials	Mark Shattuck
Coupled chemical oscillators	Kenneth Showalter (Mark Tinsley)
Instabilities in flow between concentric rotating cylinders and a bouncing jet	Harry Swinney (Bruce Rodenborn)
Nonlinear dynamics and chaos in an electro-optic system	Rajarshi Roy (Adam Cohen and Bhargava Ravoori)
Dynamics of coupled nonlinear electronic circuits	Abhijit Sen (Gautam Sethia, Mitesh Patel, and Syamal Dana)

and many small pieces of equipment needed for the experiments. Other equipment was taken by the faculty to India in suitcases and set up and tested before the opening of the school.

The Institute for Plasma Research, a large national lab with a research and engineering staff of two hundred, proved to be an excellent venue for the Hands-On Research school (figure 2). The institute is India's principal plasma physics research center. The beautiful wooded campus with striking harmonious architecture is located only four kilometers from the airport for Ahmedabad, a city of five million people located 500 kilometers north of Mumbai (Bombay), India's largest city.

The school opened on 7 January 2008, and the energy in the auditorium was evident from the start (figure 2c). The participants and faculty all knew that a major experiment, the school itself, was taking place. The director of the Institute for Plasma Research, Predhiman K. Kaw, welcomed us, and K. R. Sreenivasan described the mission of ICTP and gave the first scientific talk.

The first hands-on sessions were that afternoon. Participants were excited to see for themselves phenomena they had only read about before, and many encountered new phenomena and concepts. The enthusiasm and dedication of the participants for the laboratory sessions was remarkable. The hands-on sessions introduced apparatus that was reasonably simple yet relevant to current research, and exposed participants to many unanswered questions needing further research.

After the first day, the hands-on laboratory and modeling sessions were held each morning and were scheduled to end at 1 p.m. with lunch following at 1:30, but often participants continued working in the laboratories and had to be reminded that a catered lunch was being served out on the lawn (figure 3). Dinner for participants and faculty was served in the evening at IPR's guest hostel, where the participants were housed. Although the Gujarati food at breakfast, lunch, and dinner was different from the native foods of most participants and faculty, it was quite tasty and varied, and mild dishes were always available for those unaccustomed to the spices.

Most participants from outside of India traveled alone to Gandhinagar, some making their first trip outside of their home country, but they quickly got to know one another. The isolation of the Institute for Plasma Research from the city provided a sanctuary from distractions. The Institute organized several sightseeing outings, giving further opportunities for social interaction.

Trips to local markets were a big hit, but the highlight of the social activities centered on the International Kite Festival (Festival of Uttarayan). On Saturday evening (12 January) we were VIP guests at a cultural event that kicked off this festival. Fireworks and a speech by Narendra Modi, the Chief Minister (governor) of the state of Gujarat, were followed by a beautiful dance program celebrating the Gujarati diaspora throughout the world. On Sunday there was an outing to Modhera to see a Temple of the Hindu Sun God, built in 1026. On Monday the school participants, faculty, and staff joined the citizens of Ahmedabad in celebrating the culmination of the Uttarayan festival. We flew kites from the rooftop of a modern mall, and then feasted on a buffet lunch of traditional Gujarati food.

As the school progressed into the second week, the excitement and energy of the participants was undiminished. They continued to raise new questions and to plan for long term interactions. The new experimental and modeling projects that were initiated could keep participants and faculty connected for a long time to come.

Every participant completed an evaluation form, and the comments were overwhelmingly positive. There were also good suggestions for changes that will improve the next school: allow more time for hands-on sessions, add hands-on sessions on biological physics, and include more tutorial lectures.

The Hands-On Research school introduced laboratory methods to bright young scientists who have returned to their institutions with a new perspective and who can talk knowledgeably to their students about laboratory research. Some participants in the school plan to introduce demonstrations and/or experiments into their curricula. A crucial component in the success of the Hands-On Research school was undoubtedly the dedication and enthusiasm of the faculty, who spent much time in the previous year preparing experiments, as well as more than two weeks time traveling to and teaching in the school.

The Hands-On Research schools remain an experiment in progress, and we expect to learn much from the next school, which will be held at the Federal University of ABC at Santo André, near Sao Paulo, Brazil, 26 July – 7 August 2009. Most of the faculty from the first school have committed to participate in the Brazilian school, and additional faculty have been recruited in the area of biological physics. We plan, as suggested by the local organizers in Brazil, to leave the experiments in place after the school so that they may be used in Hands-On Research schools organized for Brazilian students. The 2010 Hands-On Research school will be in Africa.

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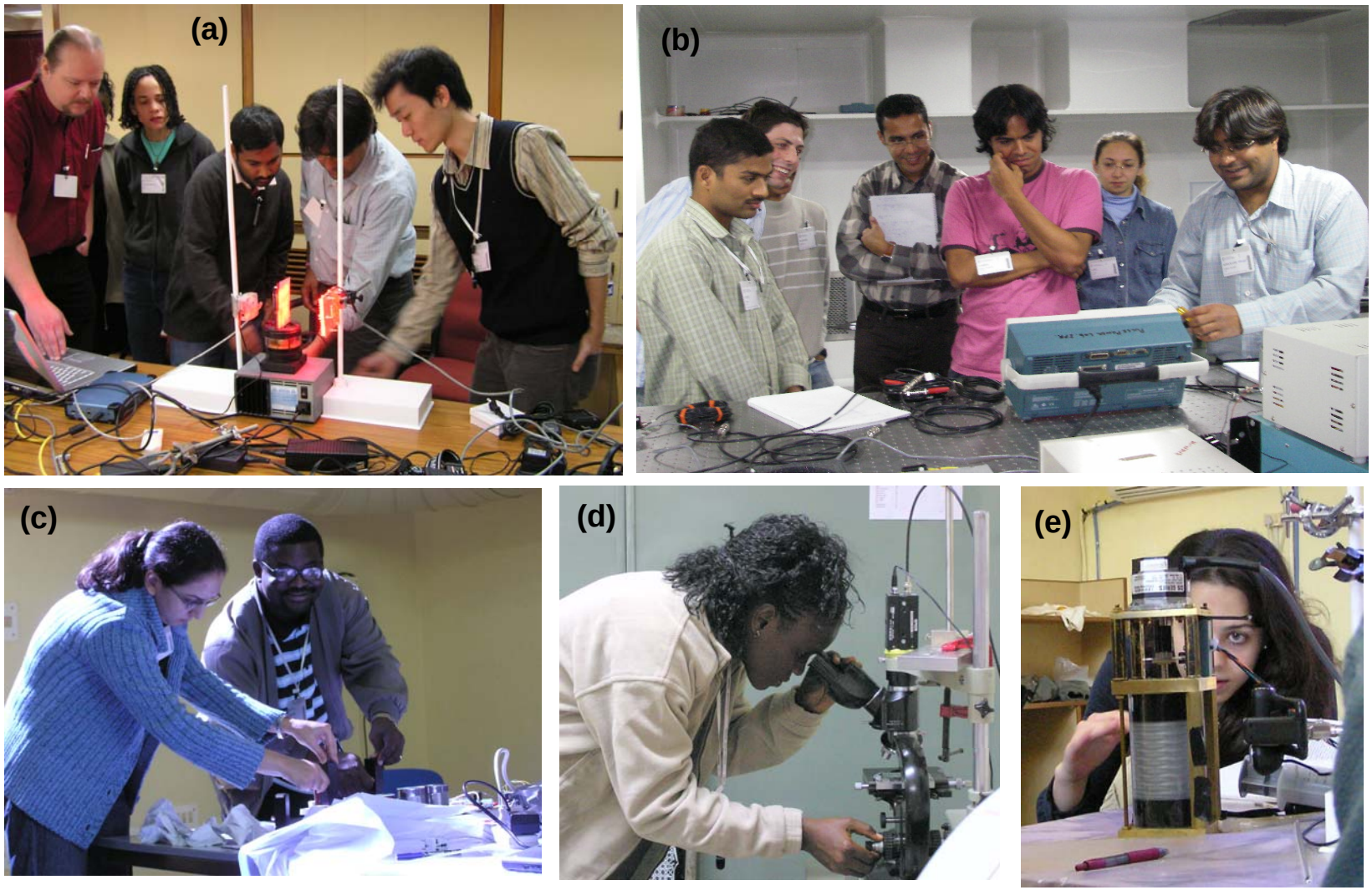

Figure 1. **(a)** Mark Shattuck (left) of the City College of New York leads a session where participants examine a phase transition in an oscillating granular sample (yellow glow) from a solid to a gas. Left to right: Folasade Dahunsi (Nigeria), Donna Comissiong (Trinidad), Katha Anki Reddy (India), Abhijeet Sonawane (India), Chun Qiao (China). **(b)** A study of chaos in a nonlinear electro-optic system. Left to right: Shekar Goud (India), Adam Cohen (U.S.), Hicham Elbelrhiti (Morocco), Andres Vahos (Columbia), Sevkan Uzel (Turkey), Abhijeet Sonawane (India). **(c)** Maniya Maleki (Iran) and Oluwole Daniel Makinde (South Africa) examine synchronization of metronomes. **(d)** Folasade Dahunsi (Nigeria) tracks particles in Brownian motion. **(e)** Hiba Sheheitli (Lebanon) observes waves on Taylor vortices, formed in a fluid flow between concentric rotating cylinders.

Figure 2. Institute for Plasma Research, site of the Hands-on Research School. **(a)** Main building. **(b)** School directors Kenneth Showalter, Rajarshi Roy, Harry Swinney, and Abhijit Sen. **(c)** Opening session in the auditorium.

Figure 3. Meals and breaks. (a) Kenneth Showalter (U.S.) and Esma'el Badran (Palestine). **(b)** Aliah Hawari (Malaysia) and Brian Storey (U.S.). **(c)** Galila Mahena (Egypt) and Gay Jane Perez (Philippines) during a poster session. **(d)** Wearing Indian dress at the Director's Dinner: Paritosh Pande (India), Bhoomi Mehta (India), Abhijeet Sonawane (India), Najoua Derbel (Tunisia), Adam Cohen (U.S.), Hiba Sheheitli (Lebanon), Chhaya Chavda (India). **(e)** Lunch on the lawn.