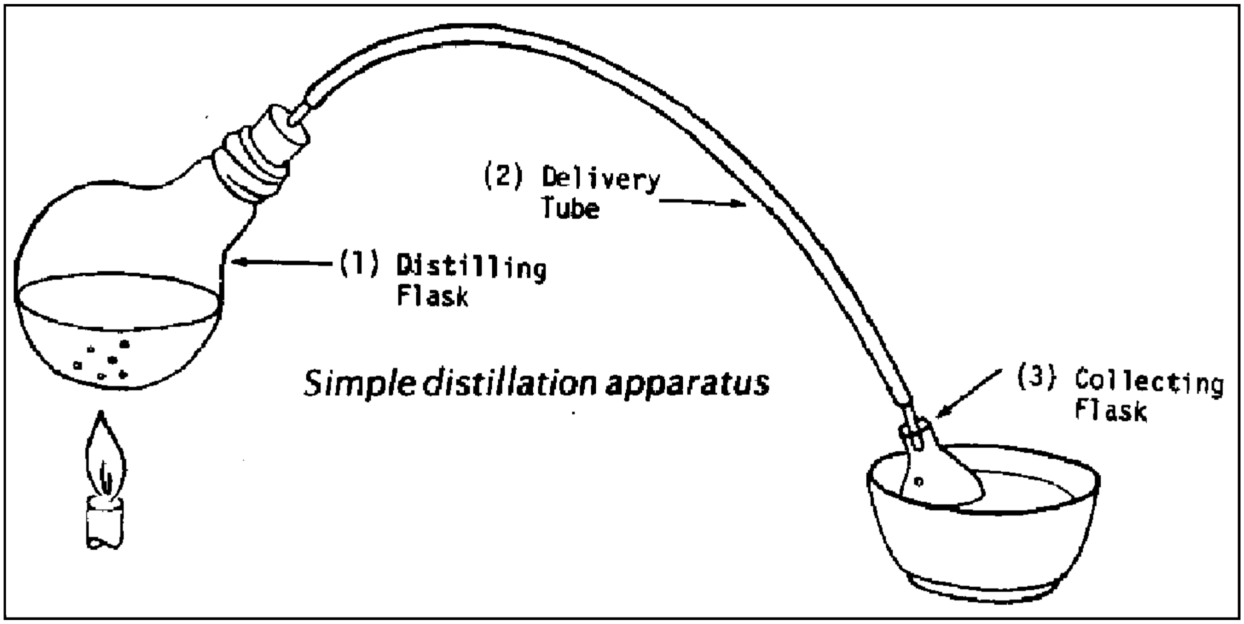

Science Teaching

It is a commonplace observation that people with little formal schooling are often quite adept at finding practical "hands on" solutions to the problems of everyday life. In the rich countries, the educated live and consume in an artificial environment of technologies too complex to be understood, much less controlled, by individuals. For most, experience with natural phenomenon and basic technical systems is very limited. Thus it is not at all surprising that relatively unschooled villagers in developing countries often demonstrate technical inventiveness and environmental understanding which astonish rich visitors. Farmers, for example, make complex decisions about which crops to plant and when, based on their knowledge of the soil and ecological interactions.

Most village-level technical innovation comes from trial and error and observations, often over many seasons. Village technology evolves as a result. But unsupported by systematic knowledge of natural science, the rate of village technology development is much slower than it could be.

Unfortunately, the science taught in schools in developing countries does not contribute to useful innovations in village technologies. Science studies should equip young people with an understanding of how to apply the basic principles of physics and biology to address a common problem (whether it be poor grain storage or a broken pump). Related skills—how to systematically control and vary a set of experimental trials, and how to carefully observe and record the results are equally important. But educational methods and curricula that are based on repetition and memorization, or inherited from a colonial past, usually mean that science teaching in the South concentrates on phenomena that are beyond the students' everyday experience, with little or no practical value.

Science education (and education in general) is, in fact, too often part of a *sorting process through which a fortunate few may escape the rural areas and qualify for an urban job in government. Science teachers, themselves the products of such a system, do not expect the community to demand that they teach a practical curriculum relevant to local conditions. These teachers are, in any case, ill-equipped to do so; in most cases science is simply one of a number of subjects the teacher is covering each day.*

As the science material taught is abstract and has little to do with local conditions, so it is natural that science teaching equipment for demonstrations is composed of what is by local standards expensive and exotic apparatus. The lucky teacher who succeeds in obtaining such apparatus from the education ministry is faced with two alternatives: to use it to demonstrate what are likely to be seen as peculiar and rather magical events, more a property of the equipment than the real world, or lock it away in a closet to prevent damage to something so valuable. In either case it is rarely (if ever) used by the students themselves, who never get a chance to get excited about science and carry out their own simple experiments.

As the books in this chapter indicate, science teaching can be something quite different. **Towards Scientific Literacy** *makes the argument that if the aim of literacy is to enable men and women to better understand the world around them, then relevant science education should be considered part of literacy, and should be included in non-formal education programs.* **The Production of School Science Equipment** *and related publications from the Commonwealth Secretariat review the problems and opportunities associated with the local production of science equipment. These educators from around the world recommend the use of objects, devices and tools from the community to illustrate scientific concepts whenever possible. Students are then more likely to see scientific principles at work in phenomena they encounter in their daily lives. Suitable curriculum development and teacher training will have to go with such equipment. The three volume set* **Guidebook to Constructing Inexpensive Science Teaching Equipment** *presents construction details for a wide variety of easily made yet sophisticated equipment that can be used to illustrate even some rather difficult scientific principles.* **A Method for Cutting Bottles, Light Bulbs, and Fluorescent Tubes** *provides instructions for making glassware for science class use.* **Adventures with a Hand Lens** *takes the science class outside, equipped with a magnifying glass, to study the natural world.* **Anti-Pollution Lab** *contains projects for students to measure the level and kind of pollutants in their community. The* **New UNESCO Sourcebook for Science Teaching**, *available in low-cost editions and in a large number of different languages remains probably the best known general science teaching reference volume.*

Many of the books reviewed in other chapters could be profitably used in practical science and technical classes. For example, books on water pumps, beneficial insects (such as **Friends of the Rice Farmer**), *and crop drying all cover scientific topics that are directly relevant to rural life. Some of these books even contain specific class projects. The* **Industrial Archaeology of Watermills and Waterpower** *examines the design evolution of waterwheels and turbines, and then presents small projects that allow school children to confirm for themselves the operating principles involved.*

After decades of neglect, it may be that one of the best ways to improve village technology is through the strengthening of the scientific problem-solving capabilities of millions of rural farmers and craftspeople. Throughout the history of the United States, it has been the farmer-inventor who has most consistently contributed successful innovations in rural technology. Although circumstances in *the South differ in some important ways, there are good reasons to believe that a similar high rate of technological improvement could be achieved, given the proper relevant science education support.*

Towards Scientific Literacy, MF 28-724, book, 96 pages, by Frederick Thomas and Allan Kondo, 1978, $15.00 postpaid from International Institute for Adult Literacy Methods, P.O. Box 13145-654, Tehran, Iran.

Towards Scientific Literacy "suggests a core curriculum of scientific ideas that should become part of the common human heritage .... Science can no longer be ignored if the aim of literacy is to enable men and women to understand better the world around them."

"Adults are *not* ignorant in science. They are already raising crops, raising children and managing their lives .... Adult education should be designed to use and develop what adults already know. The purpose of teaching science is to enable learners to improve their ability to communicate in science with experts, with peers and with their apprentices."

"Everywhere in the world there are people who look carefully at the things around them and try to understand what they see. Any person who does this is a scientist, even if he or she never studied science from a book"

"People everywhere can do experiments. Anyone who has an idea on how to improve something should do an experiment to test the idea. Perhaps a tailor has an idea for a way to sew stronger seams. If he does, he should try the new way and compare it with the old way to see which is really stronger. If a woman has an idea for a better way to store her family's food without spoiling ... she can do an experiment to see if the new idea is really better. She could store some food in the new way and some in the old way, and see for herself which stays fresher longer."

"By doing simple experiments, a farmer can learn for himself what methods are best. He can test different kinds of seed, and he can try different farming methods .... All he needs is an idea about how he might improve his crops and a small plot of land on which to test the idea."

"Some people seem to believe that only new ideas are good. A scientist does not care whether an idea is old or new. He wants to see for himself which is better."

The authors discuss a variety of science subjects, using key concepts and key words, and proposing a set of activities for teaching science in non-formal educational settings (which could also be used in a regular classroom). Subjects include soil erosion, plant nutrition, a variety of health topics, energy sources, the internal combustion engine, and electricity. The content of many of these chapters is itself rather conventional, and not directly linked to appropriate technologies. (For example, when discussing herbicides and pesticides, no attention is given to the negative side effects of these and how the farmer might discover such side effects.)

"The learning experience should be related as closely as possible to the learner's life experience." A project method is presented, in which literacy workers help farmers to identify their problems, collect local data, seek out ideas from other sources, devise a procedure for testing of possible solutions, test them, and report the results to others.

Two case studies reveal some of the potential problems and solutions in training teachers. These case studies also "show that the facts of science and procedures based upon science can be taught successfully and usefully to unschooled adults, even though they are illiterate or semi-literate."

This kind of approach could be a very important element in appropriate technology strategy, by increasing the scientific skills of the poor, and thus strengthening their capacity to find their own technological solutions.

This book is intended for use by people preparing literacy materials or training literacy staff—not for direct use by adult learners or most field workers.

Highly recommended.

The New UNESCO Source Book for Science Teaching, MF 28-728, book, 254 pages, United Nations Educational, Scientific and Cultural Organization 1979, Dfl. 21.60 from TOOL; also from UNESCO, 7 Place de Fontenoy, 75700 Paris, France; low-cost Asian edition available to countries in Asia from Charles E. Tuttle Company, 2-6, Suido l-chome, Bunkyo-ku, Tokyo, Japan 112.

This thorough book is intended for science teachers, for whom we recommend it highly. It will also be of considerable interest to others, because it describes how to make a whole range of simple equipment. There are hundreds of illustrations.

The principles of soldering are explained: you are told how to make solder and then how to use it in soldering. The composition by weight of the metals mixed to form bronze and casting brass is given, along with that of several low melting alloys.

Complete information is given on how to make the following things: simple weighing devices, a slide projector, a bunsen burner (which can illustrate the same principles to be considered when making a simple burner for biogas), several kinds of glues (including waterproof aquarium cement), soap, a dry cell battery, a simple thermometer, a model hydraulic ram, a model water wheel, and simple weather instruments such as a windspeed indicator.

Descriptions are given for the following processes: a method for depositing a bright silver mirror surface on glass; simple demonstrations of the comparative strengths of mud, clay, and sand bricks; the principles of heat transfer (important in the design of solar water heaters and insulated fireless cookers); and how to cut glass.

Another attractive feature of this book is that it suggests ways of avoiding the mold and rust on instruments associated with tropical conditions, particularly during the rainy season.

The authors' approach is to provide simple experiments or demonstrations to illustrate each scientific principle. As a science reference it is both thorough and broad in scope—covering chemistry, heat, magnetism and electricity (including circuits and fuses), wave motion, mechanics, fluids, biological sciences, rocks and minerals, astronomy and space science, and weather.

The book is intended as a guide for science teachers "for making simple equipment and for carrying out experiments using locally available materials." While it is successful in this for the most part, one possible limitation is that it does make greater use of gadgets normally found only in science labs: stands, beakers (you can make your own graduated cylinders if you have one already), two-holed rubber plugs, test tubes, and lenses. It has been translated into 30 languages (contact UNESCO at address given above for further information about this).

The Production of School Science Equipment: A Review of Developments, MF 28-727, book, 68 pages, by Keith Warren and Norman Lowe, 1975, Commonwealth Secretariat, out of print in 1985.

This is a review of the kinds of science teaching equipment that can be made domestically at lower cost than that imported from industrialized countries. Much of the book covers the work of organizations around the world and considerations for the development of appropriate science equipment.

The authors note that much beautifully designed imported equipment has suffered "because the price was totally out of reach of most schools in a developing country" and/or "it is not usable in the situation into which it has been put." Because of overemphasis on such equipment, "the majority of the children are starved of relevant practical scientific experience."

"It is possible to avoid special manufacture if there is an object already available within the country which can illustrate a concept, or replace a chemistry beaker and so on. Indeed, it may be an educational advantage to use an object which the children recognize rather than a foreign-looking object remote from their experience."

If local production is undertaken, there is a need for close collaboration between curriculum designers and apparatus designers. Also, it must be noted that if teachers are to be required to build their own apparatus, this represents a considerable time drain.

The book includes a review of activities in this field in the developing countries, along with 60 photographs of science teaching materials and kits.

Highly recommended.

Development and Production of School Science Equipment: Some Alternative Approaches, MF 28-725, booklet, 57 pages, by E. Apea and N. Lowe, 1979, Commonwealth Secretariat Publications, out of print.

This report offers a look at national curriculum and equipment development centers in India, Kenya and Turkey, and a regional center in Malaysia. The goals and organizational structure of each are described.

The most interesting of these, from the point of view of practical science education at the primary level, is the Kenya Primary Science Programme, in which a Science Equipment Production Unit has been formed. "The Programme has three basic aims: namely to encourage and assist children to: a) develop the manual and intellectual skills that are necessary to solve problems in a scientific way; b) preserve and acquire the attitudes that are necessary to apply those skills effectively; and c) acquire a deep understanding of the natural phenomena that take place in their environment .... Activities in the classroom are made to relate directly to the pupils' environment. This is accomplished by helping children first to acquire problem solving skills and then to apply the skills in solving problems based on their immediate environment."

"The use of locally available materials is important, not only in the name of economy and feasibility, but to help to prevent young children becoming alienated from their home community and background."

For the upper primary grades, "the topics for investigation will be concerned with applied science and technology, with the expectation that pupils will identify and solve problems of real and practical significance in areas such as agriculture, health and village technology."

The centers in India, Turkey, and Malaysia are primarily concerned with local production of science equipment for conventional science programs.

Low Cost Science Teaching Equipment, Report of a Commonwealth Regional Seminar/Workshop, Nassau, Bahamas, November 1976, MF 28-726, 98 pages, 1977, Commonwealth Secretariat Publications, Marlborough House, London SW1Y 5HX, England; out of print.

This report reviews the problems and progress being made in the development and production of low-cost science teaching equipment in the Caribbean, and includes recommendations for action by the governments of these nations.

"In the Caribbean, the traditional approach to science teaching —over-emphasis of teacher demonstration and learning by rote—is generally giving way to a new approach which involves inquiry, discovery, and the encouragement of pupil participation .... Unfortunately, however, basic equipment needed for this approach to science learning is sparse, or, as in most cases, non-existent. Most primary school teachers have had little or no special training in teaching science at this level. As a result ... teachers lack the confidence, knowledge and the skills that are necessary for effective science teaching, and are unable to identify potential sources in their environment that might be used in the classroom for teaching the subject." Teacher training is thus an important aspect of any strategy to develop low-cost science teaching equipment.

Experienced teachers are crucial to successful development of relevant equipment. In Kenya, "teachers formed the core of the committee that decided the original objectives; the consultant (a teacher) was a member of that committee .... The field trials, the development of the accompanying teacher training programme, the evaluation, and all aspects of production required the involvement of teachers."

Guidebook to Constructing Inexpensive Science Teaching Equipment, MF 28-720, three volumes, 968 pages total, by the Inexpensive Science Teaching Equipment Project, 1972, Science Teaching Center, University of Maryland, out of print.

This is the final product of the Inexpensive Science Teaching Equipment Project at the University of Maryland. The project set out to: "1) identify laboratory equipment considered essential for student investigations in introductory biology, chemistry and physics courses in developing countries; 2) improvise, wherever possible, equivalent inexpensive science teaching equipment."

"In designing equipment for production by students and teachers, two factors have been kept in mind. One, project work in apparatus development can be extremely rewarding for students, bringing both students and teachers into close contact with the realities of science, and relating science and technology in the simplest of ways. Two, it is not difficult for cottage (or small scale) industries to adapt these designs to their own requirements."

All the designs have been tested at the University of Maryland, but at the time these books were printed the equipment had not been produced and tested under local conditions in developing countries. A draft edition was circulated for comments from science educators around the world before the current edition was produced. These materials should therefore be considered as ideas to be tried, adapted, and improved when needed.

Only handtools are needed to make this equipment. The drawings and instructions are very clear. Some of the basic materials required will be very expensive and/or hard to obtain in some circumstances: plastic lenses, glass test tubes, corks, and metal tubes. For the most part the equipment is made of simple materials, yet often it can be used to demonstrate rather sophisticated concepts. The emphasis is on qualitative, rather than precise quantitative, measurements.

Notes on the use of the equipment are provided, but the reader will have to refer to other sources to learn how to best use some of it. Each volume has an index for all three volumes, which helps in locating equipment relevant to more than one subject area.

Construction and Use of Simple Physics Apparatus, MF 28-719, book, 36 pages, by R.F. Simpson, 1972, Swindon Book Company, Kowloon, Hong Kong, out of print.

This delightful book includes dozens of ideas for simple equipment and illustrative experiments. Everything from the behavior of ping pong balls to the use of a polished half biscuit tin as a reflector for light experiments, to the construction of hand-held stroboscopes. Written by a former school teacher who has since been training science teachers at the University of Hong Kong.

"The use of simple apparatus constructed locally provides a magnificent opportunity for educators in developing countries to extract the essence of a good science education without the expensive frills that have become associated with Western models."

In addition to the obvious advantages of very simple, inexpensive physics equipment made of commonly available objects, "pupils may become aware that scientific principles apply to everyday things and are not just associated with special apparatus, usually imported from abroad, and only found in laboratories."

A Method for Cutting Bottles, Light Bulbs, and Fluorescent Tubes, MF 28-722, 6 pages, by Allen Inversin, VITA, out of print in 1985.

These notes come from the author's efforts to find ways of making science equipment more accessible to the science teacher in developing countries. His initial use of this technique was for "cutting bottles and bulbs to make glassware for use in experiments." He has "cut hundreds of bottles of all sizes and in the process has refined the technique to the point where it should be fairly complete."

"Occasionally use can be made of cut incandescent light bulbs, as for example, beakers for boiling solutions in chemistry experiments, watch glasses, and glass chimneys for wick lamps" For this, a different technique is presented.

Adventures with a Hand Lens, MF 28-717, book, 220 pages, by Richard Headstrom, 1976, $4.50 from Dover Publications, Inc., 31 East 2nd Street, Mineola, New York 11501, USA.

This book consists of 50 explorations into the natural world using a magnifying glass, making the world outside the classroom the place where learning takes place. Basic natural principles can be taught using the simple experiments and observations. Many of the plants and insect examples are only found in temperate zones. In other regions the book could be a useful model for an approach that examines local plants and insects.

"If we look on cabbage leaves we would likely find conical, pale yellow eggs, and if we viewed them through our lens (magnifying glass) we would see that they are ribbed. The eggs are those of the imported cabbage worm .... A little later, when squash leaves have developed, the squash bug, another common insect and rather injurious to squashes and other members of the squash family, appears and lays her eggs on the leaves. They are easy to find, for they are laid in clusters and are oval and pale yellow to brown."

Anti-Pollution Lab: Elementary Research, Experiments and Science Projects on Air, Water and Solid Pollution in Your Community, MF 28-718, book, 128 pages, by Elliott H. Blaustein, 1972, Arco Publishing Company, New York, out of print.

"The great merit of Elliott Blaustein's book is to demonstrate that we can use simple and practical scientific techniques to detect pollutants as well as their effects on the body, and also to develop action programs which will once more render our environment healthy and pleasurable." (From the Preface by Rene Dubos.)

Tests included are: vital capacity measurement (lung breath volume); maximum lung breath pressure; sulfur dioxide (SO_2) air pollution; air dust particles; ozone testing; carbon dioxide (CO_2); air visibility; water turbidity; water particles; algae; detergent in water; thermal pollution; salinity; and fiber decay resistance.

A user of this book should be familiar with simple chemistry. The problem of pollution is one which is increasingly found in all parts of the planet. Industrial manufacturing in developing countries is increasingly developing and using technologies which are being banned or heavily regulated for pollution reasons in industrialized countries such as Japan and the USA. People in recently industrializing regions need information on effects of pollution and methods of pollution detection and control. This book provides a simple starting point in efforts to detect pollution.

Preserving Food by Drying: A Math/Science Manual, Peace Corps Appropriate Technology for Development Manual No. M10, MF 28-723, book, 218 pages, by Cynthia Fahey with Carl Vogel and Per Christiansen, 1980, available to Peace Corps volunteers and development workers from Peace Corps; also available from ERIC (order no. ED242558) and NTIS (accession no. PB85 243319/AS).

This innovative manual forms a curriculum for math and science study in which the students learn basic scientific concepts by constructing simple apparatus and conducting experiments. Beginning with such basics as evaporation, determination of surface area, and measurements of the sun's angles, the students then move on to study, build, and test solar food dryers. Highly recommended both for use in teaching and as a model for curriculum development in other subjects.

How to Make Tools, Peace Corps Appropriate Technology for Development Series Reprint R-35, MF 28-721, booklet, 51 pages, by Per Christiansen and Bernard Zubrowski, 1980, available free of charge to Peace Corps volunteers and development workers from Peace Corps; also available from NTIS (accession no. PB81154353).

This is the companion volume to **Preserving Food by Drying** (see review). Simple, clever designs are presented for making tools such as a hammer, drill, saw, tongs, and tweezers, as well as for a balance to weigh things. These tools are intended for use in science classes. Although some may be sturdy enough for other applications, most would not be suitable for prolonged heavy use.