GUIDEBOOK TO CONSTRUCTING

INEXPENSIVE SCIENCE TEACHING EQUIPMENT

Volume III: Physics

Inexpensive Science Teaching Equipment Project

Science Teaching Center

University of Maryland, College Park

U.S.A.

Inexpensive Science Teaching Equipment Project

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University of Maryland

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David Clark	1970-72
Chada Samba Siva Rao	1970-71

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The Guidebook is presented in three volumes:

Volume I, Biology
Volume II, Chemistry
Volume III, Physics

The following table refers only to the contents of this volume, but the listing at the back of each volume provides an alphabetical index to all three volumes.

References within the text normally indicate the volume, chapter and number of the item referred to (e.g., CHEM/V/A3), but where a reference is to an item within the same volume, the reference indicates only the chapter and number of the item (e.g. V/A3).

Within this volume the contents of each chapter are generally presented in a logical order in which items advance from simple to complex, from a point of view of both construction and educational usage.

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FOREWORD

History

The Inexpensive Science Teaching Equipment Project was initiated by Dr. J. David Lockard, and got underway under his direction in the summer of 1968. Originally entitled the Study of Inexpensive Science Teaching Equipment Worldwide (IS-TEW or IS-2 Study), the Project was 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; and (3) produce designs of this equipment in a Guidebook for use in developing countries. Financial support was provided by the U.S. Agency for International Development through the National Science Foundation.

The initial work of the Project was undertaken by Maria Penny and Mary Harbeck under the guidance of Dr. Lockard. Their major concern was the identification of equipment considered basic to the teaching of the sciences at an introductory level. An international survey was conducted, and a list of equipment to be made was compiled. A start was also made on the writing of guidelines (theoretical designs) for the construction of equipment.

Work on the development of the Guidebook itself got underway in 1970, with the arrival of Reginald F. Melton to coordinate the work. Over 200 guidelines were completed during the year by Donald Urbancic (Biology), Chada Samba Siva Rao and John Delaini (Chemistry), and Reginald Melton (Physics). Full use was made of project materials from around the world which were available in the files of the International Clearinghouse'on Science and Mathematics Curricular Developments, which is located in the Science Teaching Center of the University of Maryland. The guidelines were compiled into a draft edition of the Guidebook which was circulated in September, 1971, to some 80 science educators around the world for their comments and advice.

The work of constructing and developing equipment from the guidelines, with the subsequent production of detailed designs, began in a limited way in 1970, the major input at that time being in the field of chemistry by Chada Samba Siva Rao, who was with the project for an intensive two-month period. However, the main work of developing detailed designs from the guidelines was undertaken between 1971 and 1972 by John Delaini (Biology), Ruth Ann Butler (Chemistry) and Reginald Melton (Physics). Technical assistance was given by student helpers, with a special contribution from David Clark, who was with the project for a period of 18 months.

Thanks are due to those graduates, particularly Samuel Genova, Melvin Soboleski and Irven Spear, who undertook the development of specific items of equipment while studying at the Center on an Academic Year Institute program; to student helpers, especially Don Kallgren, Frank Cathell and Theodore Mannekin, who constructed the equipment; and to Dolores Aluise and Gail Kuehnle who typed the manuscripts.

Last, but not least, special acknowledgement is due to those individuals, and organizations, around the world who responded so willingly to the questionnaires in 1968 and to the draft edition of the Guidebook in 1971.

The Guidebook

The designs presented in the Guidebook are based on the premise that many students and teachers in developing countries will wish to make equipment for themselves. This does not mean that students and teachers are expected to produce all their own apparatus requirements. It is recognized that teachers have specific curricula to follow, and that "class hours" available for such work are very limited. It is also recognized that teachers, particularly those in developing countries, are not well paid, and often augment their salaries with supporting jobs, thus placing severe limits on the "out-of-class hours' that are available for apparatus production.

However, 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. The Guidebook should therefore not only be of value to students and teachers, but also to cottage industries which may well be the major producers of equipment for schools.

Although all the designs in the Guidebook have been tested under laboratory conditions in the University of Maryland, they have not been tested in school situations nor produced and tested under local conditions in developing countries. It is therefore recommended that the designs should be treated primarily as limited resource materials to be subjected to trial and feedback. It is suggested that the first time that an item is constructed it should be made precisely as described in the Guidebook, since variations in the materials, or the dimensions of the materials, could alter the characteristics of the apparatus. However, once this item has been tested the producer is encouraged to make any number of modifications in the design, evaluating the new products against the original.

Before producing new equipment in quantity, it is recommended that educators with experience in the field of science education should be involved in determining how best to make use of the Guidebook. They will wish to relate the apparatus to their own curriculum requirements, and, where necessary, prepare relevant descriptions of experiments which they recommend should be undertaken using the selected apparatus. They will want to subject the experiments and related equipment to trials in school situations. Only then will they consider large-scale production of apparatus from the designs in the Guidebook. At this stage educators will wish to control the quality of apparatus production, to train teachers to make the best use of the new apparatus, and to insure that adequate laboratory conditions are developed to permit full utilization of the apparatus. Too often in the past apparatus has sat unused on many a classroom shelf, simply because the teacher has been untrained in its usage, or the laboratory facilities have been inadequate, or because the apparatus available did not appear to fit the requirements of the existing curriculum. Such factors are best controlled by educators in the field of science education in each country. Clearly the science educator has a crucial role to play.

Apparatus development, like any aspect of curriculum development, should be considered as a never ending process. This Guidebook is not presented as a finished product, but as a part of this continuing process. There is no doubt that the designs in this book could usefully be extended, descriptions of experiments utilizing the apparatus could be added, and the designs themselves could be improved. No extravagant claims are made concerning the Guidebook. It is simply hoped that it will contribute to the continuing process of development.

TOOLS AND RAW MATERIALS

The raw materials required to make specific items of equipment are indicated at the beginning of each item description. However, there are certain tools and materials which are useful in any equipment construction workshop, and these are listed below.

Tools

Chisels, Wood

3, 6, 12, 24 mm
(i.e., 1/8", 1/4", 1/2", 1")

Cutters

Bench Shears: 3 mm (1/8")
Glass Cutter
knife
Razor Blades
Scissors: 200 mm (8")
Snips (Tinmans), Straight: 200 mm (8")
Snips (Tinmans), Curved: 200 mm (*")
Taps and Dies: 3 to 12 mm (1/8" to 1/2") set

Drills and Borers

Cork Borer Set
Countersink, 90°
Metal Drill Holder (Electrically Driven), Capacity 6 mm (1/4")
Metal Drills: 0.5, 1, 2, 3, 4, 5, 6, 7 mm
(i.e., 1/32", 1/16", 3/32", 1/8", 5/32", 3/16", 7/32", 1/4") set
Wood Brace with Ratchet: 250 mm (10")
Wood Augur, Bits: 6, 12, 18, 24 mm
(i.e., 1/4", 1/2", 3/4", 1')

Files, Double Cut

Flat: 100 mm, 200 mm (4" 8")
Round: 100 mm, 200 mm (4', *")
Triangular: 100 mm (4")

Hammers

Ball Pein: 125, 250, (1/4, 1/2 lb)
Claw 250 g (1/2 lb)

Measuring Aids

Caliper, Inside
Caliper, Outside
Caliper, Vernier (may replace above two items)
Dividers: 150 mm (6"), Toolmakers
Meter, Electrical (Multipurpose - volts, ohms, amps, etc.)
Meter Stick
Protractor
Scriber

Measuring Aids (Continued)

Set Square
Square, Carpenter's: 300 mm (12") blade
Spoke Shave: 18 mm (3/4")
Wood Smoothing Plane

Pliers

Combination: 150 mm(6")
Needle Nose: 150 mm (6")
Side Cutting: 150 mm (6")
Vise Grips

Saws, Metal

300 mm (.2") blades

Saws, Wood

Back Saw: 200, 300 mm (8", 12")
Coping Saw: 200 mm (8")
Cross Cut: 600 mm (24")
Hand Rip: 600 mm (24")
Key Hole Saw: 200 mm (8")

Screw Drivers

100 mm (4") with 2 and 3 mm tips
150 mm (6"), with 5 mm tip
200 mm (8"), with 7 mm tip

Vises

Metal Bench Vise: 75 mm (3")
Wood Bench Vise: 150 mm (6")

Miscellaneous

Asbestos Pads
Goggles, Glass
Oil Can: 1/2 liter (1 pint)
Oil Stone, Double Faced
Punch, Center
Sandpaper and Carborundum Paper, Assorted grades
Soldering Iron: 60 watts, 100 watts

Raw Materials

Adhesives

All Purpose Cement (Elmers, Duco)
Epoxy Resin & Hardener (Araldite)
Rubber Cement (Rugy)
Wood Glue (Weldwood)
Cellophane Tape
Plastic Tape
Masking Tape

Electrical Materials

Bulbs with Holders: 1.2, 2.5, 6.2 volts
Dry Cells: 1.5, 6 volts
Electrical Wire: Cotton or Plastic covered
Fuse Wire: Assorted
Lamps: 50, 75, 100 watts
*Magnet Wire: #20, 22, 24, 26, 28, 30, 32, 34
Nichrome Wire: Assorted
Parallel Electrical Cording
Plugs
Switches

Glass and Plastic

Acrylic (Plastic) Sheets: 2 cm and 2.5 cm thick
Plates, Glass
Tubes, Glass: 3, 6 mm (1/8", 1/4") internal diameter

Hardware

Bolts and Nuts, Brass or Steel; 3 mm (1/8") diameter: 12, 24, 48 mm (1/2", 1", 2") lengths
Nails: 12, 24mm (1/2", 1") lengths
Screws, Eye
Screws, Wood: 12, 18, 24, 26 mm (1/2", 3/4, 1", 1 1/2")
Thumbtacks
Washers (Brass and Steel): 6, 9 mm (1/4", 5/16") diameter
Wingnuts (Steel): 5 mm (3/16")

Lumber

Boxwood (Packing Case Material)
Hardboard: 6 mm (1/4") thick
Kiln Dried Wood: 2.5 x 15 cm (1" x 6") cross section
1.2 x 15 cm (1/2" x 6") cross section
Plywood: 6, 12 mm (1/4", 1/2") thickness
Wood Dowels: 6, 12 mm (1/4", 1/2") thickness

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* U. S. Standard Plate numbers are used in this book to indicate the gauge of different wires. Where wires are referenced against other numbering systems appropriate corrections should be made in determining the gauges of materials required. The following comparison of gauges may be of interest:

Standard	Diameter of #20 Wire
Brown & Sharp	0.08118
Birmingham or Stubs	0.089
Washburn & Moen	0.0884
Imperial or British Standard	0.0914
Stubs' Steel	0.409
U. S. Standard Plate	0.09525

Metal Sheets

Aluminum: 0.2, 0.4 mm (l/100", 1/64") thickness.
Brass: 0.4, 0.8 mm (1/64", 1/32") thickness.
Galvanized Iron: 0.4 mm (1/64") thickness.
Lead: 0.1 mm (1/250") thickness.
Spring Steel, Packing Case Bands

Metal Tubes:

Aluminum, Brass, Copper: 6, 12 mm (1/4", 1/2") internal diameter.

Metal Wires

Aluminum: 3 mm (1/8") diameter
Coathanger: 2 mm (1/16") diameter
*Copper: #20, 24
Galvanized Iron: 2 mm (1/16") diameter
*Steel: #20, 26, 30.

Paint Materials

Paint Brushes
Paint Thinner
Varnish
Wood Filler

Miscellaneous

Aluminum Foil
Cardboard Sheeting
Containers (Plastic or Glass)
Corks (Rubber or Cork)

Hinges: Assorted
Machine Oil
Marbles
Mesh (Cotton, Nylon, Wire)
Modelling Clay (Plasticene)
Paper Clips
Pens: Felt (Marking Pens)
Pins and Needles
Rubber Bands
Soldering Lead
Soldering Paste
Spools
Steel Wool
Straws
String (Cord,.Cotton, Nylon)
Styrofoam
Syringes: Assorted
Wax (Paraffin)

*See footnote on previous page.