

Low-Cost Science Teaching Equipment:3

Report of a Commonwealth
Regional Seminar-Workshop

Lae, Papua New Guinea
19-30 March 1979



Commonwealth Secretariat

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Commonwealth Secretariat, Marlborough House, London SW1

COMMONWEALTH SECRETARIAT

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INTRODUCTION

The Commonwealth Secretariat's Education Division has now completed the third seminar-workshop on Low-Cost Science Teaching Equipment conducted in the various regions of the Commonwealth. It is possible therefore to trace certain strands of common experience that have emerged. First, it is clear that the subject is one of general concern to educational authorities in all countries. Second, the problems encountered exist in all countries though to a more acute degree in some than in others. Third, it has emerged that the experience described in the workshops has been applicable and relevant to a very high degree in solving the problems identified. And throughout the series, the importance of relevance, especially in science education and the correlation of curricula with educational equipment have been repeatedly emphasized.

At each of the seminar-workshops participants have expressed a determination to move increasingly towards greater self-reliance in procurement of resources while recognizing the value of Commonwealth and international co-operation as a vital step in pursuit of that goal. It is encouraging to Commonwealth efforts so far that reports from member states indicate that some welcome changes have already begun to occur as a result, slowly though these may be appearing. The various items of equipment produced at the third workshop as well as two previous ones indicate, in some measure, the degree to which the immediate objectives of the series have been achieved.

Our plans to follow up these developments will be formulated on the basis of the very valuable information gathered from the series, as part of our clearing-house efforts in Commonwealth education.

The Commonwealth Secretariat wishes to acknowledge its gratitude to the Government of Papua New Guinea for its kind hospitality in hosting this workshop, and for the facilities it so generously provided through the University of Technology. Special thanks are due to the University for the hospitality and the resources it made available through the Department of Applied Physics. Our thanks are also due to the chairman and alternate chairman who steered the sessions so well; to the consultants for their invaluable contribution; to the Department of Education and University Co-ordinators; to the delegates for their hard work; to our observers of whom some played the part of resource persons; and finally to our rapporteurs and typists who often worked late into the night.

The workshop-seminar was funded by the Commonwealth Fund for Technical Co-operation.

Education Division
Commonwealth Secretariat

BACKGROUND AND ARRANGEMENTS

Objectives

Like the earlier meetings, this workshop was organized by the Education Division and funded by the Commonwealth Fund for Technical Co-operation, as part of the Commonwealth Secretariat's efforts to assist member countries to make school science teaching more effective but less costly through the use of locally-made equipment. More specifically, the workshop was held to: consider methods by which school science equipment is most effectively developed and the implications for teacher education of effective teacher participation in innovative strategies of teaching through the use of low-cost science equipment; provide workshop experience in designing, developing and evaluating locally-constructed low-cost science equipment; examine ways of improving Commonwealth co-operation, especially in the field of production and use of school science equipment.

Venue

At the Seventh Commonwealth Education Conference held in Accra in March 1977, ministers recommended that a third workshop on low-cost science teaching equipment be held in either the Pacific or Asia. The first two workshops on the theme were held in the Bahamas (November 1976) and Tanzania (September 1977) respectively.

The Government of Papua New Guinea kindly offered excellent hosting facilities at the University of Technology, Lae, thus enabling this third workshop to be held for the Commonwealth Pacific countries.

Delegates and Observers

All Commonwealth Pacific independent countries and the associated states of the region were invited to be represented. Eventually, delegates attended from Fiji, New Zealand, Papua New Guinea, Solomon Islands, Tonga, and Northern Territories (Australia). Inter-Regional representatives came from Guyana (Caribbean) and Malaysia (Asia). Also in attendance were observers from Papua New Guinea, the British Council, UNESCO/UNDP and the South Pacific Appropriate Technology Development Unit. Participants included school teachers, lecturers from teachers' colleges and universities, curriculum development experts and ministry of education officials in charge of production units and/or responsible for the supply of school science equipment.

Consultants

The workshop was privileged to have Mr Norman Lowe of Britain and Dr Sam T. Bajah of Nigeria, as workshop consultants.

Mr Lowe, a freelance consultant on production of science teaching equipment, is a co-author of the Commonwealth Secretariat publication, The Production of School Science Equipment; he was formerly UNESCO expert at the Science Equipment Centre in Nigeria and at the National Science Centre at Afghanistan as well as consultant to UNESCO.

Dr Bajah is a senior lecturer at the International Centre for Educational Evaluation at the University of Ibadan, Nigeria and a member of the Nigeria's UNESCO National Commission. He has published a number of books and papers on science education and has served as consultant to the Science Education Programme for Africa (SEPA) and UNESCO on several occasions.

Workshop Secretariat

Mr K. Pitzz, First Assistant Secretary and Mr G. Ilagi, Assistant Secretary (both from the Department of Education, Ministry of Education, Science and Culture) served as Workshop Chairman and Alternate Chairman respectively. Mr Rex E. O. Akpofure, Director of Education, Commonwealth Secretariat, was the Director of the Workshop. Mr E. Apea, a Chief Project Officer (Education), Commonwealth Secretariat, was the Workshop Secretary. Other staff included Mr Brian Deutrom, Senior Curriculum Officer (Science), Department of Education, Papua New Guinea, Mr Bruce Cahill, Co-ordinator, Materials Development and Evaluation, Department of Education, Papua New Guinea, Prof. E. Balasubramaniam, Dr P. Logan, Mr Ian Brazier, Mrs Margaret van Der Werff and Mr B. Isom - all of the University of Technology, Lae.

Opening Ceremony

The Opening Ceremony was held at the Duncanson Hall, University of Technology, Lae, at 11.00 a.m. on Tuesday 20 March 1979. The ceremony which was preceded by refreshments served at the Applied Physics Department began with a welcome address by Mr M. Tigilai, Vice-Chancellor of the University of Technology, Lae. In his address, Mr Tigilai provided information on the development of the University and invited participants to move freely around the campus to meet the staff and see the resources and facilities of the various departments.

His Excellency Mr Donald Middleton, British High Commissioner to Papua New Guinea, then formally opened the workshop on behalf of the Government of Papua New Guinea. He warned participants not to spend too much time attempting to define the term "low-cost"; but instead to show that it is possible for developing countries to produce suitable, appropriate equipment. He pointed out that the international nature of the workshop indicated that there were many solutions to the equipment problem.

Mr Rex E. O. Akpofure, the Director of the Workshop, responded to the opening address on behalf of the Commonwealth Secretariat. He indicated that the workshop was the third and last in a series organized by the Commonwealth Secretariat as part of its efforts to help make practical science teaching less costly but more effective through local production of low-cost equipment. He noted that the workshop represented a belief in the value of interaction and mutual co-operation by Commonwealth countries, pointing out how suitable Papua New Guinea was as a venue.

Mr Pitzz, First Assistant Secretary, Ministry of Education and Culture, gave the closing remarks. He apologized for the absence of the Honourable Minister of Education, Science and Culture and the Secretary for Education. He welcomed participants to Papua New Guinea and wished the workshop a successful period of exchange of ideas.

At the end of the ceremony a group photograph was taken. This was then followed by a press conference at which Messrs Pitzz and Akpofure, the principal speakers, explained the purpose of the meeting, outlined the ten-day workshop programme, and gave an insight to possible post-workshop Commonwealth Secretariat follow-up efforts.

Distinguished guests in attendance were Mr M. Tigilai and Mr Davidson, the University of Technology's Vice-Chancellor and Pro Vice-Chancellor respectively, Mr R. Lohia, Vice-Chancellor of the University of Papua New Guinea, Port Moresby, and H.E. Mr D. Middleton, British High Commissioner to Papua New Guinea. The press included the Post-Courier, Lae Nius, the National Broadcasting Commission, and the University Reporter, Lae.

Workshop Sessions

There were altogether 34 sessions of which eight were devoted to country reports and six to lead papers at plenary and group discussions. Also, 15 sessions were devoted to practical laboratory work at which participants not only familiarized themselves with laboratory techniques but actually produced items of science equipment.

Participants made visits to a cross-section of educational institutions in Lae. Also worthy of special mention was the excursion to Wau (about 100km. from Lae) which acquainted participants with the scientific work being carried out at the Wau Ecology Institute.

Hospitality

In honour of participants to the workshop, receptions were hosted by the Government of Papua New Guinea on 20 March, the Papua New Guinea University of Technology on 22 March and the Commonwealth Secretariat on 29 March.

WORKSHOP RECOMMENDATIONS

Recommendations to Pacific Commonwealth Governments

Commonwealth South Pacific Governments are called upon to:

1. Determine and declare an appropriate degree of priority to be accorded to science education within the national context.
2. Identify and spell out the objectives of science education in their national institutions within the context of its overall National Development Plan, and the stated objectives of its educational policy.
3. Establish where they do not already exist, and adequately staff, curriculum development units in order to evolve curricula that serve the country's national needs through education, so as to ensure that what is taught in educational institutions is relevant to such needs.
4. Establish within such curriculum development units a science equipment development section wherever one does not exist. The aim of such a section should be to ensure the availability of science equipment and materials in schools and colleges at minimum cost by whatever means are appropriate to the national education system, including repair and maintenance, selective importation, and local production from prototypes.
5. Support the teaching of science on a practical basis at all levels of education by making adequate provision for teachers as well as equipment so as to provide a sound foundation for producing scientists, technologists and technicians.
6. Regard in-service training both locally and overseas as a regular, continuous exercise, designed to up-grade knowledge and skills, especially those of the science teachers in the rapidly expanding body of scientific information. Such in-service training should equip untrained teachers with urgently needed basic training and up-date the skills of already trained teachers. In this connection the assistance of the Commonwealth Secretariat as well as Unesco, and other international and regional bodies should be explored.
7. Regard the well-planned pre-service training of all teachers in science education as essential. Such training should include exposure to national curricula and training in the use of local resources and production of low-cost science equipment.
8. Provide scholarships/bursaries, including study visits and attachments for persons working in science education, to enable them to receive training at suitable centres in curriculum development, and the maintenance and production of science equipment and materials.

9. Encourage active collaboration between Ministries/Departments of Education, Industries, Works, Agriculture, Health and other relevant science-oriented Departments of Government as well as appropriate private-sector organizations in order to develop and ensure the use of suitable locally available science equipment and materials. Collaboration should also encourage the use of common educational programmes.
10. Ensure, through appropriate legislation, that where importation is necessary, science equipment, chemicals and material required for the local production of science teaching equipment is imported at the lowest possible cost and with the minimum of delay.
11. Encourage the formation of national Science Teachers' Associations in countries of the region where they do not already exist, and support their national and international roles where such Associations do exist, if necessary by seeking the assistance of international and regional agencies having special interest in science education (e.g. CASME, ICASE, UNESCO, UNICEF and RECSAM).
12. Provide, in view of the general shortage of experienced science teachers and ancillary staff, career incentives in order to attract and retain such science education personnel at all levels. Such incentives would include avenues for promotion within the various cadres, official contribution towards the travel costs of approved in-service training meetings, and professional recognition of in-service courses for purposes of advancement for serving officers, as well as special allowances for science teachers.

For Regional Action

13. All Commonwealth South Pacific Governments are invited to increase their regional co-operation in education and, in particular, in science education through the establishment of a Commonwealth South Pacific Science Equipment Centre as proposed in the following annexe. Such a centre will assist in reducing the problems of availability of low-cost science equipment in member states through improved importation mechanisms, maintenance, local development and production of suitable equipment relevant to national curricula.

ANNEX TO RECOMMENDATION 13

COMMONWEALTH SOUTH PACIFIC SCIENCE EQUIPMENT CENTRE

It was recommended that the above proposed centre should have the following aims and objectives, structure and management:

Aims and Objectives

- (a) To assist member countries in ensuring the availability of science equipment and materials in schools and colleges at the minimum cost possible and by whatever means are appropriate to their national education systems.
- (b) To pursue in consultation with governments all relevant steps which will encourage the effective teaching of science through availability of science equipment materials in the region.
- (c) To set up or encourage the setting up of national science equipment centres within curriculum units in ministries of education in member countries in the region and to maintain liaison with these centres in order to ensure that the provision of equipment is always directly related to their curricula.
- (d) To maintain constant liaison with other regional centres throughout the Commonwealth and in other countries engaged in similar activities.
- (e) To assist with the setting up of national and local production and distribution centres wherever economically appropriate.

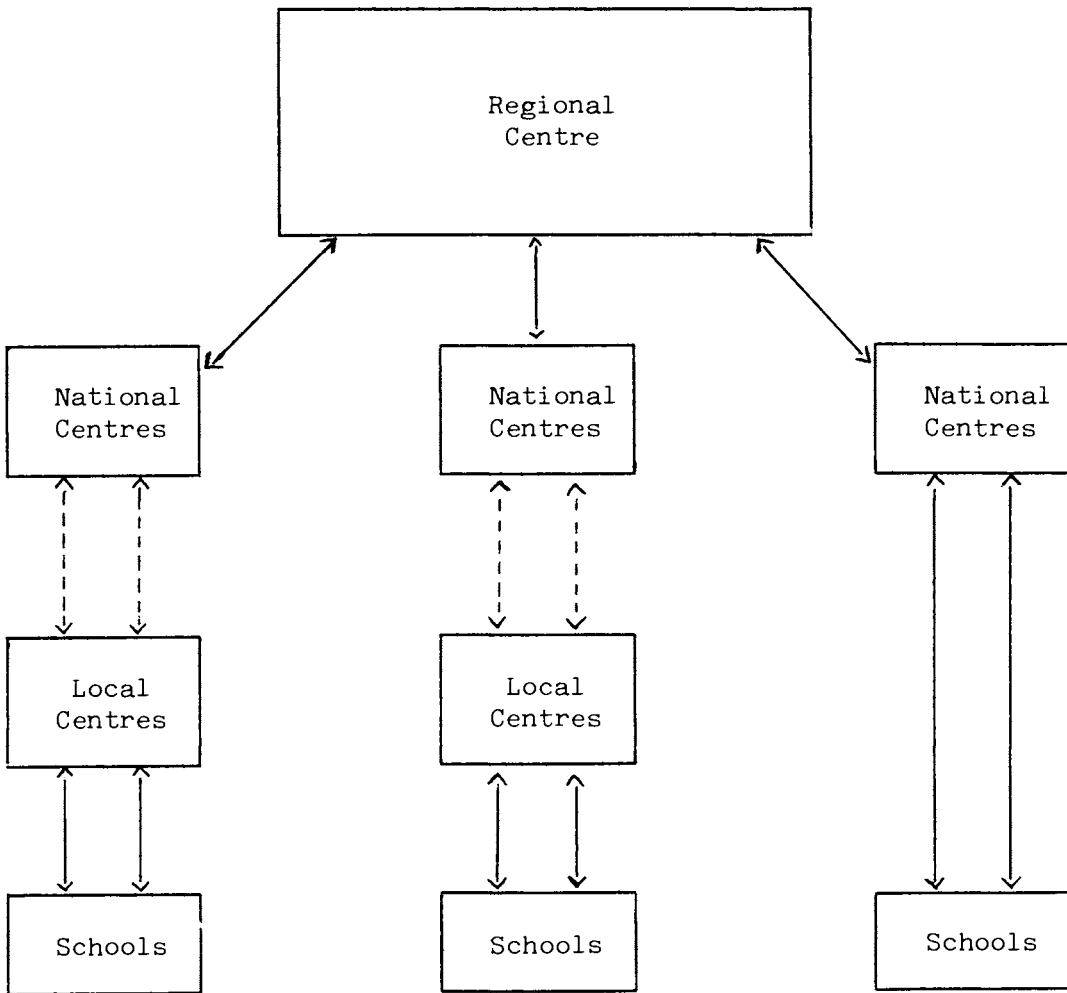
Structure and Management

A governing council should be established consisting of Permanent Secretaries or Secretaries for Education of Commonwealth governments of the region, as well as representatives of relevant regional organizations which shall report to the Regional Meetings of the Ministers of Education.

Funding

Initially, a request should be forwarded by the governments of the region to the Commonwealth Secretariat to assist with the establishment of the Centre. It is envisaged, however, that a phased programme of contributions by member governments will enable the Centre to be wholly supported from within the region.

Suggested Structure of the Regional and National Equipment Centres



National Science Equipment Centre(s)

Without delay each member country should establish a national equipment centre. This centre should be closely related to, or be part of, the curriculum development centre or unit of the Ministry of Education and should:

- (a) Ensure, at the minimum cost, the availability of suitable science equipment and materials in schools and colleges.
- (b) Pursue all relevant steps which will encourage the effective teaching of science through availability of low-cost equipment and materials.
- (c) Establish and maintain, wherever appropriate, a local centre or centres. For example, these could begin as units in suitable, strategically located educational institutions teaching industrial arts or manual skills. Such units should be equipped and used to produce, as part of the institution's curriculum, science equipment items (e.g. test-tube racks, clamps, stands) so as to improve local availability, and reduce supply and distribution problems.
- (d) Maintain constant liaison with the regional centre, once it is established (see diagram on page 8) and other national centres within the region.
- (e) Review present distribution systems of science materials to schools and wherever necessary make changes to improve the efficiency of these systems.

SUMMARY OF DISCUSSIONS

In discussing the subject of Low-Cost Science Teaching Equipment it was understood that science includes Mathematics and other related areas

LOW-COST SCIENCE TEACHING EQUIPMENT: TRAINING FOR PRODUCTION

Existing Sources of Equipment

Each country reported on the present situation regarding the supply of equipment and chemicals to their schools. Initially, or at some later stage, funds and/or equipment had been obtained through aid programmes but subsequent replacement of items or provision for an expanding system of schools was the responsibility of the countries themselves. This often led to the replacement of the more expensive items (e.g. UNICEF spirit lamps) by cheaper locally-made items (e.g. glass bottles with rag wicks). When items had to be imported, they generally came from traditional suppliers in the United Kingdom such as Griffin and George or Phillip Harris. Some supplies, particularly chemicals, were obtained through Australian or New Zealand firms such as Selbys. Generally, suppliers of science equipment or chemicals were not represented in the various countries.

As to why supplies were not obtained from the USA or from such areas in Asia as Singapore, Hong Kong or Taiwan, it was found that former traditional suppliers in UK were supported mainly because of the relative ease and of foreign exchange dealings. Often Asian suppliers preferred to work through Australian or New Zealand agents thus increasing their prices.

All countries reported long delays (typically six months but occasionally up to two years) from the time orders were placed until final delivery to individual schools. In the Pacific distribution over a wide area, breakage, and loss of items were ever-present problems.

Some items were available locally in each country through government stores or from purchases in commercial and private local stores. Items which could be recycled (e.g. plastic bags, cans, disposable syringes) were a major local source of equipment.

Funding was a problem in each country. Any funds available came directly from the ministry, from school fees or from self-help projects of parents and citizen/parents and teachers groups. Generally, funds were available on a school-wide basis with headteachers having final responsibility for division of votes among various subject areas. As a result no definite funds for procurement of science equipment or chemicals were known in advance. It appeared that typical science funding was of the order of 20c to 50c per primary school pupil and \$1 to \$1.50 per secondary school student.

Disbursement of such funds tended to be through the ministry for primary schools with more direct ordering for some secondary schools. Some

bulk ordering by a number of government ministries or a group of schools in a country did occur. Buying agents such as the Crown Agents were not used.

Maintenance, Repair and Production

Few schools, and then only at upper secondary level, in Fiji and Papua New Guinea had laboratory support staff who generally had very little training. Teaching staff were quite often too inexperienced themselves to carry out maintenance and repair. Thus equipment requiring repair was often put aside and neglected. A particular problem was that containers of chemicals deteriorated, occasionally with disastrous results.

A general lack of secure storage areas in most schools was reported; the most common procedure being storage of boxed kits in the headteacher's office or other such secure area. In some cases (e.g. secondary schools) adequate storage facilities were planned when building schools, but schools often operated long before any equipment arrived.

Apart from Australia and New Zealand, only Papua New Guinea and Fiji were producing equipment and even then only at the prototype stage. Fiji reported that a proposal was being considered to set up an equipment centre. In Papua New Guinea staff were in training for equipment production but these were to be more of administrators rather than actual producers.

The large amount of improvisation already implemented by practising teachers was noted together with efforts being made in teachers' colleges for students to produce as part of their training some items of equipment for their own use.

Activities in Other Areas, and Possibilities for the Pacific Region

The operations of the Scottish Schools Science Equipment Research Centre in Edinburgh, and the Consortium of Local Education Authorities for the Provision of Science Equipment in London were explained, and examples of their work displayed. Production units such as those established in Kenya, Turkey and Afghanistan were also considered. This resulted in a discussion of the possibility of setting up a regional equipment centre in the Pacific area. Recognizing the shortfalls and problems including limited funding within the Pacific area, and possible advantages seen by the establishment of such a centre, the delegates to the workshop recommended that a Pacific Regional Equipment Centre for Science should be established.

Roles of Specific Persons

The roles of teachers, curriculum development officers, financing officers, headmasters and other administrators in obtaining adequate low-cost equipment for science in the schools was considered only briefly. It was agreed, however, that the efforts of individual teachers should be acknowledged (e.g. by incentives) and further encouraged. Clearly identified objectives for national science programmes at each level of education should be set by all administrators, and where necessary priorities arranged.

LOW-COST SCIENCE TEACHING EQUIPMENT:
TRAINING FOR USE

Practical Work in Science

Although practical work in science was considered to be essential, it was reported that many schools in the South Pacific region did little or no practical work. In some cases this was due to lack of science equipment resulting from a rapid expansion of education systems and a failure to equip new schools adequately. In others it was due to a lack of scientific background among teachers; a lack of training in the use of equipment; a failure to see the relevance of experiments in developing concepts; heavy teaching loads; large class sizes and related problems of discipline; pressure to cover syllabus in which practical work was often not directly included in a student's final assessment; and lack of a laboratory attendant.

A number of suggestions to overcome the problems and difficulties were considered. They included lighter teaching loads for science teachers to allow for adequate preparation for experiments; timetabling designed to provide free periods before practical classes; and smaller laboratory classes. It was also suggested that in order to be seen as a really important component of science teaching, practical work should be relevant to the science curriculum and be made part of the assessment procedures.

Choosing Equipment

Many factors influence the choice of items of equipment for developing an understanding and appreciation of a particular science concept. They include the intellectual level, maturity, and manipulation skills of the pupils; suitability of the equipment for the objectives of a particular lesson; cost; storage facilities and requirements; and subsequent maintenance and repairs.

It was suggested that the ministry of education in each Commonwealth South Pacific country should prepare guidelines indicating basic equipment requirements for teaching the current national science curricula. An example of such a document, prepared by the Malaysian Curriculum Development Centre for teaching integrated science, was shown to participants.

The advantages of having special kits of equipment include suitability for storage and portability, since in the Pacific region few classrooms have sufficient security for storing separate items of equipment. There is a tendency, however, on the part of some teachers not to use any of the equipment in a kit if parts are missing or broken.

As far as possible students using low-cost equipment should perform experiments themselves rather than watch a teacher demonstrating them. It was recognized, however, that there are occasions when demonstration needs to be used for pedagogic and economic reasons.

Problems Association with the Use of Equipment

Problems related to ordering, distribution, storage, maintenance and repair were discussed. They are summarized in the discussion on the sub-theme, Training for Production. Further problems relating to the effective use of equipment were considered. They included lack of manipulative skill among teachers a failure to understand how to demonstrate specific concepts in a practical way. As mentioned above, many teachers find they have insufficient time or skill to set up apparatus or to try out new experiments for themselves. In the Pacific region, understanding instructions in a foreign language or in technical English is often a problem, and it was recommended that simplified English instructions should be given wherever possible.

There is an obvious need for assistance for the teacher, and each of the participants was urged to convince his or her home government of the need to employ laboratory assistants. Such assistants could set up equipment, help with practical classes, and store, maintain and repair equipment.

Training of Teachers in the Use of Equipment

Pre-service, in-service and on-the-job training are all necessary for the most effective use of equipment in science teaching. Training is needed to give teachers a satisfactory knowledge and understanding of basic science concepts and of the curriculum they will be teaching. The philosophy behind the particular curriculum and the psychological principles involved in its teaching should be understood, and experience in handling all equipment used with the science curriculum should be included.

Many other aspects of the training of science teachers were considered. Among these were the design, production, evaluation, and simple maintenance and repair of equipment; and the development of a resource bank consisting of such materials as newspapers, journals, magazines and diagnostic tests.

Pre-Service Training of Teachers

For adequate pre-service training, teacher training institutions should have laboratories with suitable storage and workshop areas. The training situation must as far as possible match that of a typical classroom. In the primary teachers' colleges especially, improvisation, using cheap materials such as bottles, empty cans and plastic bags, should be encouraged. New Zealand and Fiji reported on teachers' colleges which have set up model school laboratories with school-type equipment.

One problem with courses at teachers' colleges is the lack of time for adequate training. Furthermore, the academic background of incoming students is often low and has to be improved before they can learn about teaching.

Suggested programmes for secondary-level teacher training should include practical work in science, technical skills, courses in repair and maintenance of science equipment, and lessons in graphic art.

In-Service Training of Teachers

The type of in-service programmes mounted must depend on the academic background and training experience of the teachers. In-service activities should be used to upgrade teachers' knowledge, teaching methods and skills; introduce

and train in the maintenance and repair of equipment; involve teachers in the revision of curricula; and produce worksheets and other classroom materials.

It was pointed out that in-service training sessions should be a continual, ongoing service to teachers and could be of varying duration. The need for structured, well-organized, possibly national programmes, was noted. Such in-service training exercises should call upon the human and physical resources of training colleges, existing science education organizations, and national or regional equipment centres. Suggestions were made for identifying suitable in-service centres among existing institutions such as schools and audio-visual centres.

Some participants commented on the inability of in-service programmes to motivate teachers in their countries. It was suggested that teachers may be motivated if a programme is relevant to the classroom situation, if it is practically oriented, and if it offers some chance for self-improvement. Expenses for teachers attending courses should be paid, and the programmes should be considered as a factor for promotion.

The Role of Science Teachers' Organizations

There is a need for teachers to belong to organizations such as the Commonwealth Association of Science and Mathematics Educators (CASME) and the International Council of Associations for Science Education (ICASE). Science teachers' organizations can contribute to the general improvement of science education and should be recognized and encouraged by ministries of education.

A science teachers' organization may assist teachers through participation in curriculum work, distributing equipment and materials, and in developing tests and item banks. In addition, the organization can exchange ideas and information among members and with other organizations elsewhere. When considered necessary, a science teachers' organization can act as a pressure group in obtaining policy changes for science education.

Participants were reminded that all such improvements require changes in attitude towards science, particularly by educational administrators, heads of science departments in schools, headteachers, inspectors, curriculum officers, planning and finance officers, and chief education officers.

COMMONWEALTH CO-OPERATION IN EDUCATION
WITH SPECIAL REFERENCE TO SCIENCE EDUCATION

The paper presented on the above subject gave an overview of the activities of the Education Division of the Commonwealth Secretariat and its relationship to other bodies. Special emphasis was placed on co-operation in science education between member countries within the South Pacific area.

Collection and Dissemination of Information

Ways in which the Secretariat acts as a clearing-house for information about educational development were explained. Information is collected and disseminated (a) through staff liaison visits to, and attendance at conferences in, various countries; (b) from visitors to the Secretariat; (c) through correspondence, journals, periodicals, and conference reports; and (d) through special studies and surveys undertaken by the Secretariat. It was noted with pleasure that in each member country the Ministry of Education now has a "desk-officer" who works closely with the Secretariat in the collection and dissemination of educational information.

Attention was drawn to the fact that although Secretariat publications are copyrighted, permission to republish them locally is usually granted, if requested, at no charge.

Meetings

The scope of these activities range from triennial ministerial conferences, through pan-Commonwealth specialist conferences to smaller regional workshops, seminars and symposia on special topics in education. It was explained that the Secretariat is paying increasing attention to the seminars/workshops such as this one, where some measure of training is provided. It is envisaged that this type of meeting would lead to participants going home and training other people in the subjects covered by the workshop.

Training

The Commonwealth Secretariat, with the support of the Commonwealth Fund for Technical Co-operation (CFTC) provides support for training of personnel in Third World countries in the following ways:

- (a) Bursaries or scholarships enable personnel, particularly middle-level personnel, to train at existing courses in other Third World countries. The courses at the Regional Educational Centre for Science and Mathematics (RECSAM) in Malaysia, and the Colombo Plan Staff College for Technical Education in Singapore, were cited as examples.
- (b) Provision of consultants to assist in training programmes.

(c) Organization of special regional courses such as the one held in Fiji from May to July 1978 for the Pacific Region on educational administration and supervision.

(d) Educational visits for personnel to examine special areas of interest in other developing countries. Emphasis is now being given to attachment to an institution rather than to brief visits.

The function and role of CFTC was explained. In particular, it was noted that CFTC funds are not available for capital projects, and the training generally supported is limited to Third World Commonwealth countries.

Teaching About the Commonwealth

As a result of strong support given by Commonwealth Heads of Government in 1977, the Secretariat is mounting educational programmes to improve knowledge and understanding of the modern Commonwealth and the activities undertaken within its framework.

Commonwealth Associations

The Secretariat offers support to some non-governmental organizations such as the Commonwealth Association of Science and Mathematics Educators (CASME) and the Commonwealth Association of Polytechnics in Africa.

Inter-Regional Co-operation

The presence of representatives from Guyana and Malaysia was used to illustrate how we can learn from experimentation, successes and failures in other regions.

Co-operation in Science Education in the Commonwealth Pacific Countries

From earlier discussions at the Workshop it was apparent that many problems of science teaching in the Pacific Region were similar to those in other parts of the Commonwealth. Accordingly, a number of recommendations for effective co-operation were made.

PRACTICAL LABORATORY SESSIONS

The Laboratory sessions were prominent in the workshop - a total of 22½ hours (47%) out of 48 hours being devoted to practical laboratory sessions. These laboratory sessions were organized in four phases; exploration, demonstration and practice, working in groups, and plenary sessions.

Phase One: Exploration session

A number of printed curricular materials and some low-cost science equipment were displayed. The printed materials included those from the Curriculum Unit, Ministry of Education, Papua New Guinea; the Department of Education, Wellington, New Zealand, the Curriculum Development Centre, Canberra Australia; and selected from the United Kingdom and Nigeria. The low-cost science equipment included physics, chemistry and biology kits from the School Equipment Production Unit (SEPU), Kenya; a water-drop microscope, a spring balance made from bamboo, thermal expansion apparatus, and a ball-point pen thermometer developed at the Appropriate Technology Development Unit based at the PNG University of Technology, Lae; and a double beam balance, a ray optics set, and metre rules developed at the Materials Development Unit, Education Department, Port Moresby.

The main focus of this session was to make the participants aware of the rich potential for local production of simple items of equipment. While examining the apparatus on display, participants were asked to consider, amongst others, the following basic questions:

- (a) Is the apparatus suitable for children's use, considering the age range as being up to early secondary-level education, particularly in relation to the accompanying printed material?
- (b) What advantages/disadvantages are there when comparing the larger composite kits of SEPU to the smaller topic kits (e.g. optics kit) included in the Papua New Guinea apparatus?
- (c) What advantages/disadvantages are there when considering kits of apparatus as distinct from equipping a laboratory with individual items?

The participants showed a lot of interest in the material on display.

Phase Two: Demonstration and Practice Session

Several different demonstrations were carried out by the consultants and resource persons.

Allen Inverssin showed such techniques as cutting glass bottles, making dyes from local plants and electrolysis of sodium chloride solution using simple, locally made electrolytic cells.

Norman Lowe showed such techniques as glass cutting, making pipettes, scaling glass tubes, cutting by polystyrene hot wire and hot-wire technique for cutting glass tubing (fluorescent light tubes).

Mike Davis showed the technique of drilling glass plates and bottles using a copper bit and carborundum powder.

The demonstrations were followed by sessions during which participants had a chance to practise the special techniques to which they had been exposed.

Phase Three: Working in Groups

Participants were assigned to groups (three or four in each group). Each group was asked to examine the PNG curriculum materials and pick out two units (one from primary and another from secondary) and design suitable low-cost equipment for them. The detailed guide-lines for the group work was as follows:

- (a) Identify two topics - one primary and one secondary
- (b) Decide on equipment
- (c) Prepare and design specification
- (d) Construct prototype
- (e) Prepare a teachers' guide to include the method of construction and the use of the prototype equipment.
- (f) Evaluate the equipment and teachers' guide produced.

The list below shows the specific tasks undertaken by each group.

Group	Primary Level Task	Secondary Level Task
A	Light: Circular disc	Electricity: hydro-electricity
B	Electricity: Lighting more than one bulb at the same time	Comparative expansion of liquids (using solar energy)
C	Electromagnetism: model to demonstrate electromagnetism	Energy: transformation of energy (model hydro-electric generator)
D	i) Light: various types of pin-hole cameras using different types of local materials ii) Wooden box for storage of spirit burners	i) Insect cages for students ii) Wooden box for storage of spirit burners iii) A potometer to measure transpiration in leafy plants.
E	The Electric Buzzer	Device in creating electric current

The detailed construction exercises are as shown in pages 88 to 122.

SUMMARY OF COUNTRY REPORTS

SCIENCE EDUCATION IN SCHOOLS IN COMMONWEALTH SOUTH PACIFIC COUNTRIES

In order to achieve a good exchange of information at the workshop, participating countries from the South Pacific region were asked to provide country papers on science education programmes, including efforts being made to equip schools with suitable apparatus. These country reports were presented by representatives from Australia (Northern Territory), Fiji, New Zealand, Papua New Guinea, Solomon Islands, and Tonga. The Inter-Regional representative from Guyana also provided a similar report.

As expected, there are similarities in the structures of the education systems within the region. Curriculum development units, where these exist, are responsible through permanent secretaries or secretaries of education to politically appointed ministers. Also, high turnover of staff, difficulties relating to equipping and maintaining school science laboratories and over-dependence on expatriate teachers especially at the secondary level are common problems.

Summaries of country reports based on papers presented and results of workshop discussions are as follows:

Australia (Northern Territory)

There are approximately 50 non-aboriginal and 60 aboriginal primary schools, eight secondary and three residential aboriginal secondary schools, and one primary teachers' college in the Territory. The school children come from a variety of backgrounds, speak a plethora of languages, are scattered sparsely over a large area and suffer from unemployment when they leave school.

Primary School Level: Science, has until recently not been actively promoted in primary schools. The Primary School Science of the Territory (PSST) is at present being developed and will be systematically phased into the non-aboriginal primary schools. The aboriginal community and out-station schools do not have a Territory-wide science programme.

Secondary School Level: Secondary students undertake five years of schooling leading to the year 12 South Australian Public Examinations Board's matriculation examinations. Generally, the students take a general science course for the first three years. Some integrated science is taught and many approaches and types of materials, both Australian and overseas, are used. In the last two years of secondary schooling (i.e. years 9 and 10) students specialize in the usual disciplines of Biology, Geology, Chemistry and Physics.

Aboriginal secondary students attend one of the three residential colleges before enrolling in the "normal" secondary schools under the guidance of counsellors.

Teacher Education: Primary school teacher training with a significant component of science education recently commenced at the Darwin Community College.

All secondary school science teachers receive their training either in other Australian states or overseas. There are at present few full-blood aboriginal school teachers although a large number are employed as teacher aides and can with experience and further training become full-time teachers.

Science Equipment: There appears to be little effort directed towards the development of science teaching equipment at the local level.

Non-aboriginal primary schools are beset by cumbersome ordering procedures and inadequate storage facilities. Secondary schools generally order equipment through the bulk ordering system of the South Australian Education Department, and are generously supplied with laboratory assistants who also carry out repair and maintenance of equipment.

Two national science curriculum projects - the Australian Science Education Project (ASEP) and the Australian version of the American Intermediate Science Curriculum Study (ISCS) - have resulted in the production of some low-cost equipment for Australia-wide usage.

Fiji

There are about 650 primary schools in the country.

A Nature Science course has for many years been part of the primary education curriculum. In 1973 development commenced on a new primary science programme known as Elementary Science and based closely on the Papua New Guinea primary science curriculum. The course is discovery-oriented, activity-based and rooted in the environment, and has been implemented in all years 1 to 3 classes. Development of years 4 to 6 material is planned.

Secondary Science Education: There are two types of secondary schools, namely Junior Secondary Schools (years 7 to 10) and Senior Secondary Schools (years 7 to 11) or (years 7 to 12).

All schools follow the Basic Science programme in years 7 and 8. This is an integrated science programme developed for regional implementation by the University of the South Pacific. Some schools follow a separate science programme in years 9 and 10, but most continue with the Basic Science programme. Students write the Fiji Junior Examination at the end of year 10.

At the end of year 11 students sit for the New Zealand School Certificate examination in Physical and Biological Sciences or in separate science subjects.

Year 12 students study separate science subjects leading to the New Zealand University Entrance Examination (NZUE).

Training of Teachers: Primary school teachers are trained in primary teachers' colleges. At these colleges most students undergo a two-year training programme which includes a course in science education.

To combat a severe shortage of teachers in rural areas, a licensing system exists by which untrained, unemployed school leavers are allowed to teach in primary schools. These teachers can, on gaining some years of experience, undertake a one-year teacher training course.

The introduction of the Elementary Science programme in primary schools has required considerable re-orientation of the existing teaching force. Hence, since 1977, extensive in-service programmes at which, amongst others, teachers are taught how to use certain items of equipment, have been organized throughout the country.

All secondary science teachers are trained at the University of the South Pacific. Courses offered are:

- (a) Diploma in Education - a three-year course for post-NZUE students.
- (b) Concurrent B.Sc. with Graduate Certificate in Education - a five-year course for post-NZUE students.
- (c) B.Ed. - a four-year course for post-NZUE students or a two-year course for holders of a Diploma in Education.
- (d) Postgraduate Certificate in Teaching for untrained holders of a B.Sc. and teaching experience.

Science Equipment: The Elementary Science course in primary schools is an activity-oriented one, and as such requires various items of equipment. 700 kits of equipment consisting of several items supplied by UNICEF and others purchased locally have been distributed to all primary schools. The distribution of these kits is carried out during in-service courses for teachers.

Teachers are also encouraged to make simple items of equipment, following instructions found in teachers handbooks, from locally available materials.

All secondary science equipment is purchased from overseas. In the absence of a central procurement and distribution centre, schools order their individual requirements. Government schools receive a financial allocation for the purchase of equipment.

New Zealand

There are some 2500 primary schools and 300 secondary schools in New Zealand, attended by about 520,000 and 234,000 students respectively.

Primary schools (years 1-8), contributing schools (years 1-6) and intermediate schools (years 7 and 8) are classified as primary institutions. Area schools (years 7-13) and high schools (years 9-13) are classified as secondary schools.

Seven three-year primary teachers' colleges train teachers for the primary schools. In association with local universities some colleges run courses leading to diplomas and degrees in education. There are two secondary teachers' colleges.

Primary School Level: Originally primary school science was associated with Nature Study or biological science. However, recent years have seen the evolution of a new science syllabus for years 1-6. This new, integrated science course is planned around four broad areas of scientific knowledge and experiences - matter, energy, time/space, and living things. Objectives are the development of process skills, interests and attitudes, communication skills, concepts and acquisition of knowledge.

A major feature of this development is the production of units of work including statements of objectives, suggested activities and teacher notes. Equipment has also been supplied.

Years 7 and 8 students at primary schools study the first two years of a newly developed middle school science syllabus.

Secondary School Level: In recent years the years 7 to 10 science syllabus developed in the '60s has been under revision. A new draft syllabus with guide was distributed to schools in 1978, and combined primary/secondary working parties are preparing teacher guides for the syllabus. It is planned to issue sets of equipment when the syllabus and guide are completed.

Year 11 students may choose to take general science and/or biology or chemistry or physics. At present 40 trial schools offer courses in Biological Science, Physical Science and Alternative Science.

Years 12 and 13 students elect to take one or more of Physics, Chemistry or Biology.

Training of Teachers: Most primary teachers enter a teachers' college with University Entrance or a Higher School Certificate. The three-year training period includes a minimum of approximately 30 hours related to science education in primary schools, and some students elect to take science as a major course.

Prospective secondary school science teachers take a three- or four-year degree before undertaking a one-year course of teacher training at a teachers' college.

Some teachers' colleges conduct in-service courses ranging from one day to several weeks' duration. Science teachers' organizations run workshops during evenings and week-ends. Besides, there are 27 full-time primary science advisors and two secondary advisors who conduct in-service courses, mostly in schools.

Science Equipment: Equipment is supplied to all schools by the Department of Education. The basic equipment supplied to individual schools is determined by a committee representing all interested groups and is periodically reviewed and updated. In addition, schools receive yearly capitations, part of which may be used in acquiring additional equipment.

Equipment kits related to the new primary syllabus have recently been issued to schools. These kits contain some locally-made items. The Rehabilitation League (an organization which provides employment for physically and mentally handicapped people) have been responsible for making many of the items in the sets, and for their packaging and distribution. Similar kits are planned for years 7 and 8. All new schools receive a basic issue of equipment and a setting-up grant.

Science Inspectors and Curriculum Officers specify minimum standards and specifications for equipment, test samples of goods from tenders, and decide which is the "best" for each school level.

Papua New Guinea

There are 2050 Community Schools (years 1-6), about 100 Provincial High Schools (years 7-10) and four National High Schools (years 11 and 12). Ten teachers' colleges prepare teachers for the Community Schools, and the University of Papua New Guinea trains secondary teachers at its Goroka Campus. All science curriculum development, evaluation and examinations are co-ordinated by one officer of the Curriculum Unit.

Primary School Level: The science course, introduced into some schools in 1968 under a UNESCO/UNDP project, has gradually replaced an existing Nature Science programme. It consists of one 30 to 40 minute lesson/activity per week and introduces children to both biological and physical science. The material available includes teachers' handbooks, an equipment kit, and a set of basic reference books for teachers. There is also a weekly radio broadcast for children in years 5 and 6.

Secondary School Level: In all Provincial High Schools integrated science is a core subject leading up to Schools Certificate Examinations at the end of year 10. The development of the current course, which began in 1971 under the auspices of a UNESCO/UNDP programme, was preceded by a situation in which there were a variety of overseas courses. The government adopted the course in 1975. The production of relevant and suitable material for teachers and pupils is one characteristic of the course.

Selected students undertake separate sciences in years 11 and 12 at the four National High Schools.

Training of Teachers: Ten teachers' colleges train teachers for Community Schools. All these colleges follow a common core science course developed in 1977. In-service programmes for Community School teachers focus on basic concepts and processes of science and aim at building the teachers facility and confidence in teaching science. Most entrants to the two-year course are year 10 graduates.

Science teachers for Provincial High Schools are trained at the Goroka campus of the University of Papua New Guinea. The course is of three year duration for year 10 graduates. 80% - 90% of years 7 and 8 classes and about 40% - 50% of year 9 and 10 classes are taught science by Papua New Guineans.

All science staff for National High Schools (i.e. years 11 and 12) are at present recruited from overseas.

Science Equipment: The primary science programme is an example of an integrated science course which uses a mixture of standard and local resource materials. The standard kit of equipment consists of about 16 items originally supplied by UNICEF, and another two dozen or so items purchased locally. Each kit caters for 40 pupils and is housed in a lockable cabinet.

Two thousand kits and large quantities of replacement parts have been purchased and distributed. But the problems of distribution, storage, security, and maintenance, contribute largely to the fact that to date many schools are not fully equipped. Secondary science equipment has been received through international and bilateral aid programmes. Unfortunately many of the items received are relevant only to western science curricula and teachers.

Facilities for repair and maintenance of equipment are either non-existent or, where they exist, very expensive. This, coupled with the inability of teachers to improvise and modify equipment, means that large quantities of equipment now lie idle and are deteriorating in schools.

National High Schools were given large establishment grants which have been followed by generous annual budgets. Community School Teachers' Colleges purchase science equipment out of their normal budget allocation, and the Goroka Teachers' College has and continues to receive generous budget allocations for science.

Teachers in Community Schools have always been encouraged to make simple pieces of equipment from local materials. This practice has been encouraged in the teachers' handbooks, the Community Schools science syllabus and during all in-service programmes.

Teachers' guides, teacher training, and in-service programmes for high schools teachers, also emphasize the making of simple items of equipment.

The Ministry's newly established equipment production centre is producing prototypes of equipment which are needed to teach the secondary science course.

Solomon Islands

There are about 200 Primary Schools, 15 sub-junior or Provincial High Schools and six National Secondary Schools.

Primary School Level: Prior to 1971 primary schools followed a variety of natural science courses. The current course, the Solomon Islands Environmental Approach to Science (SIEAS) programme, is UNESCO-funded and emphasizes discovery-learning and the skills of communication, observation, measurement and classification of equipment.

Secondary School Level: The sub-junior or Provincial High Schools have until recently been extensions of existing primary schools. Recent policy to upgrade these institutions includes proposals to include the teaching of basic science principles and processes through the teaching of agriculture.

Integrated science is a core subject at National Secondary Schools, and the course leads to the year 11 Solomon Islands School Certificate examination. A few selected students go on to separate science courses in year 12 before writing the Cambridge Overseas Certificate examination. The development of resource materials, setting and marking of examinations, in-service training, and further development of the curricula for National Secondary Schools is undertaken for the Ministry of Education by a committee of practising science teachers.

Training of Teachers: The Solomon Islands Teachers College prepares teachers to teach the SIEAS programme in primary schools. The College also acts as a centre for in-service programmes to familiarize teachers with SIEAS, and as a storage and distribution point for UNESCO science equipment kits. The majority of science teachers for secondary schools are recruited from overseas.

Science Equipment: Primary and sub-junior secondary schools using the SIEAS programme are supplied with a kit of equipment by UNESCO. Teachers are expected to supplement this equipment and are provided with information in the teachers' guide on how to construct simple equipment using local materials, and of the sources of useful items such as wire, syringes etc. Self-reliance is encouraged and practised. Problems faced include lack of storage and repair facilities, teacher apathy and a shortage of top-up and replacement items.

All secondary science equipment is purchased from overseas. Schools at present make individual orders and are not able to take advantage of bulk buying.

Harsh climatic conditions and low levels of maintenance and repair skills take a heavy toll on sensitive equipment. The Secondary Science Panel runs in-service courses and attempts to co-ordinate the dissemination of information on the construction, procurement, and exchange of equipment.

Tonga

Primary education has been compulsory since 1876. All primary-age and 85% of secondary-age children attend the 133 primary and 48 secondary schools of this Pacific Kingdom. One teachers' college prepares teachers for the primary school level.

Science is included in the subject Nature Study at primary school; emphasis here is on direct observation of nature and on developing scientific attitudes. The teaching of science as a component of Nature Study has not been successful and this has led to efforts being made to develop, with Australian aid, an "Environmental Science" programme particularly for the fifth and sixth year classes.

The majority of secondary schools follow the long established General Science Syllabus, a traditional science course leading to the Tongan Higher Leaving Examination in the tenth year.

Tonga participated as an inaugural member country in the development of the UNDP/UNESCO basic Science Programme based at the University of the South Pacific in Fiji. Ten secondary schools began trying out this curriculum in 1971, and it was envisaged that all schools would gradually follow suit. For a variety of reasons however, this has not happened. Nevertheless, the Tongan Science Teachers Association still supports the programme and from time to time organizes activities including regular in-service courses aimed at promoting effective teaching and learning.

Less than 10% of tenth year students go on to the eleventh and twelfth years of schooling and undertake courses leading to the writing of overseas (particularly from New Zealand) examinations.

Teacher training at the one and only teachers' college is restricted to the preparation of primary school teachers; the two-year course produced with the help of UNDP emphasizes the acquisition of basic physical and biological science principles.

There is no specific training of secondary science teachers, and the Kingdom relies heavily on expatriates (principally American Peace Corps) and a few New Zealand-trained Tongans.

Most science equipment used in secondary schools and in the teachers' college is imported from overseas; the United Kingdom is the largest single supplier. A diversity of education agencies; the absence of central ordering, storage, maintenance and repair facilities; a shortage of trained, experienced science teachers; and geographic isolation, contribute to the existing school equipment problems. In 1972 a UNDP-sponsored investigative project demonstrated that a limited range of science equipment items could be constructed locally, but there has been little follow up to this exercise.

EVALUATION OF THE SEMINAR/WORKSHOP

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Introduction

Evaluation is looked upon in different ways by different people. But basically, evaluation of educational programmes is undertaken to clarify issues. Alkin (1970) refers to evaluation as the process by which relevant data are collected and transformed into information for decision making. Because evaluation normally implies use of systematic processes of data collection, it has also been referred to as 'objective reporting'. Objectivity is a key issue in any evaluation process.

This workshop is the third in the series of similar workshops, and all the agencies involved in the planning, organization and execution are interested in objective reporting. No reports exist of any formal evaluation of the earlier workshops, and it was considered necessary to formally evaluate this third workshop to obtain, among other things, the perception of the participants with regard to this and future workshops. Information so obtained will be useful to the Commonwealth Secretariat and perhaps to other organizations in planning similar workshops in future.

Data for this evaluation were obtained by means of a questionnaire administered to all the participants at the end of the workshop. A copy of the questionnaire is as shown on pages 83 to 87.

Results

Of the 21 participants who submitted completed questionnaires, ten (i.e. 47.62%) were university graduates and 11 (i.e. 52.38%) were not. The working experience of the participants ranged from one to 15 years. A number of the participants were attending an international seminar on low-cost equipment for the first time. Table 1 shows the frequency of attendance at national and international seminars on low-cost science teaching equipment.

Table 1: Attendance at Low-Cost Science Teaching Equipment Seminars

Frequency	National		International	
	No. attended	%	No. attended	%
Never	8	38.10	0	0.00
Once	6	28.57	20	95.24
Two times	3	14.28	1	4.76
Three times	0	0.00	0	0.00
More than three times	4	19.05	0	0.00
Total	21	100.00	21	100.00

Table 2 shows a summary of how information about the workshop reached the participants.

Table 2: Information about the Workshop

Method	No. of Participants	%
Contacted by National Ministry of Education	14	66.67
Contacted by Commonwealth Secretariat	4	19.05
Contacted by National Government	1	4.76
Contacted by Academic Institution	1	4.76
Contacted by National Science Teachers' Association	1	4.76
Total	21	100.00

The participants who came to the workshop were either sponsored by their national government or by the Commonwealth Secretariat. Table 3 shows the degree of sponsorship of participants.

Table 3: Agency Responsible for Sponsorship to Workshop

Specification	Sponsor			
	Commonwealth Secretariat		National Government	
	No. sponsored	%	No. sponsored	%
Round trip fare	13	61.90	8	38.10
Hotel accommodation	14	66.67	7	33.33
Feeding	14	66.67	7	33.33

Although this workshop was supposed to be a regional one, participants had to travel long distances to arrive at the workshop venue. They used two different means of transportation - air and road. Table 4 shows how the participants travelled to the workshop.

Table 4: Mode of Travel to Workshop

Method	Number of Participants	%
By air	20	95.24
By road	1	4.76
Total	21	100.00

The second part of the questionnaire focused attention on specific aspects of the workshop. In particular, participants were asked to give their opinions on facilities provided during the workshop, their assessment of the lead papers and the laboratory sessions. Table 5 shows a summary of participants' ratings of the workshop facilities.

Table 5: Participants' Ratings of Workshop Facilities

Specific Aspects	Good(3)		Fair(2)		Rating Poor(1)		Mean
	No.	%	No.	%	No.	%	
Arrangement for obtaining travel ticket	17	85.00	2	10.00	1	5.00	2.80
Arrangement for meeting participants on arrival	16	80.00	3	15.00	1	5.00	2.75
Hotel accommodation	9	45.00	9	45.00	2	10.00	2.35
Arrangement for visits to schools	11	57.89	8	42.11	0	0.00	2.58
Arrangements for excursions	10	50.00	8	40.00	2	10.00	2.40
Daily transportation	11	52.38	9	42.86	1	4.76	2.60

Tables 6, 7, and 8 give summaries of the participants' ratings on the three lead papers.

Table 6: Participants' Rating of Lead Paper 1*

Specific Aspect	Adequate/Satisfactory (3)		Rating Fair (2)		Inadequate/ Unsatisfactory (1)		Mean
	No.	%	No.	%	No.	%	
Content	13	61.91	7	33.33	1	4.76	2.57
Presentation	14	70.00	6	30.00	0	0.00	2.70
Time allocation for presentation	13	68.42	6	31.58	0	0.00	2.68
Time spent on group discussion	12	63.16	7	36.84	0	0.00	2.63
Presentation of group reports	17	80.95	4	19.05	0	0.00	2.81
Time spent on plenary discussion	14	66.67	7	33.33	0	0.00	2.67

* Title: Low-Cost Science Teaching Equipment: Training for Production

Table 7: Participants' Rating of Lead Paper 2*

Specific Aspect	Rating						Mean
	Adequate/Satisfactory (3)		Fair (2)		Inadequate/Unsatisfactory		
	No.	%	No.	%	No.	%	
Content	16	76.19	5	23.81	0	0.00	2.76
Presentation	16	76.19	5	23.81	0	0.00	2.76
Time allocation for presentation	19	90.48	2	9.52	0	0.00	2.90
Time spent on group discussion	15	71.43	6	28.57	0	0.00	2.71
Presentation of group reports	14	66.67	7	33.33	0	0.00	2.57
Time spent on plenary discussion	13	61.90	8	38.10	0	0.00	2.62

* Title: Low-Cost Science Teaching Equipment: Training for Use

Table 8: Participants Rating of Lead Paper 3*

Specific Aspect	Rating						Mean
	Adequate/Satisfactory (3)		Fair (2)		Inadequate/Unsatisfactory		
	No.	%	No.	%	No.	%	
Content	18	90.00	2	10.00	0	0.00	2.90
Presentation	14	70.00	6	30.00	0	0.00	2.70
Time allocation for presentation	13	68.00	6	31.58	0	0.00	2.68
Time allocation for discussion	12	60.00	7	35.00	1.0	5.00	2.55

* Title: Commonwealth Co-operation in Education, with Special Reference to Science Teaching Equipment

A major part of the time spent during the workshop was devoted to the practical laboratory sessions in which participants were guided in the making of simple science teaching equipment. Table 9 gives a summary of the participants' rating of the laboratory sessions.

Table 9: Participants' Rating of Laboratory Session

Specific Aspects	Rating						Mean
	Satisfactory/ Useful or Adequate (3)		Fair		Unsatisfactory/ Not Useful or Inadequate		
	No.	%	No.	%	No.	%	
Organization	9	47.37	10	52.63	0	0.00	2.47
Experience gained	16	80.00	4	20.00	0	0.00	2.80
Tools provided	18	90.00	2	10.00	0	0.00	2.90
Materials provided	19	95.00	1	5.00	0	0.00	2.95

The third part of the questionnaire sought to obtain the perception of the participants on low-cost science equipment in general. Statements about production and use were presented to the participants and they were expected to react to each on a three-point scale - agree, not sure, disagree. Table 10 summarizes the reaction of the participants to the 15 statements.

Table 10: Participants' Perception of Low-Cost Science Equipment

Statement	Rating		
	Agree %	Not sure %	Disagree %
1. Low-cost science equipment will be inadequate for teaching Primary Science in my country	0.00	9.52	90.48
2. Low-cost science equipment will be <u>adequate</u> for teaching <u>High School Science</u> in my country	61.90	19.05	19.05
3. At the present moment, the production of low-cost science equipment will be feasible in my country	57.14	42.86	0.00
4. Teachers in my country will not be enthusiastic in the use of low-cost science equipment	5.00	40.00	55.00
5. The use of low-cost science equipment will help students become interested in further work in science	80.95	19.05	0.00
6. The use of low-cost science equipment will make science more relevant to the environment of the learner	90.48	9.52	0.00
7. Teachers in my country are not sufficiently trained to use low-cost science equipment	57.14	28.57	14.29

Continuation of Table 10

Statement	Rating		
	Agree %	Not sure %	Disagree %
8. In-service workshops should be frequently organized for teachers who use low-cost science equipment	90.48	4.76	4.76
9. Classroom science teachers should be involved in the mass production of low-cost science equipment	60.00	10.00	30.00
10. Results obtained using low-cost science equipment are grossly inaccurate	0.00	35.00	65.00
11. Low-cost science equipment should only be used in Teacher Training Colleges	0.00	0.00	100.00
12. The use of low-cost science equipment is inappropriate in industrially advanced countries	4.76	23.81	71.43
13. The production of low-cost science equipment should NOT be undertaken at the regional level but at the national level	42.86	14.29	42.86
14. Low-cost science equipment is not suitable for practical <u>examinations</u>	4.76	23.81	71.43
15. Low-cost science equipment leads to a <u>cheap</u> but ineffective way of teaching science	14.29	4.76	80.95

The fourth part of the questionnaire dealt with the free-response type of questions. Six questions about the workshop were presented to the participants who were asked to respond freely. While an attempt was made to extract all the information provided in the responses, only a summary of statements with appreciable frequency (i.e. above 30%) are included in this evaluation report.

FREE RESPONSE

- Question 1. What is it you like best in this workshop?
- (i) Opportunity to exchange ideas on low-cost equipment.
 - (ii) Opportunity to learn how an international workshop on low-cost science equipment is organized.
 - (iii) Opportunity to learn more about the Commonwealth Secretariat.
 - (iv) Opportunity to learn at first hand how low-cost science equipment is produced.

Question 2.

What is it you dislike most in this workshop?

- (i) Long sessions until 5.30 - 6.00 p.m.
- (ii) Important discussion coming up at end of day when participants are tired.
- (iii) Inability of Commonwealth Secretariat staff to be more involved in the sessions.
- (iv) Wasting of time before catching the bus in the mornings.
- (v) The time-table was too tight.

Question 3.

What is it you would have liked to see done in this workshop which was not done?

- (i) More field trips to PNG schools to enable the participants to appreciate fully the problems of using low-cost science equipment in PNG schools.
- (ii) Evaluation of materials produced not done in actual PNG schools.
- (iii) More time needed for discussion of 'mass production' of low-cost science equipment.
- (iv) Bringing of more models and prototypes from various countries.
- (v) More group discussion on current science education problems of the South Pacific Region.
- (vi) More emphasis given to the construction of charts and models.
- (vii) More discussion with consultants on problems and experiences with low-cost science equipment in teacher training.

Question 4.

What would you suggest for inclusion in a workshop of this nature in future in the Pacific?

- (i) A taste of PNG traditional life especially for participants from other countries.
- (ii) Evaluation Reports of previous workshops to be provided.
- (iii) More time for production of equipment.
- (iv) More demonstration of techniques and use of various low-cost equipment.
- (v) More papers from countries on how the problems of production and use of low-cost science equipment were solved.

- (vi) A session on curriculum development strategies.

Question 5. How useful has this workshop been to you personally?

- (i) Realization of problems of other countries on production of low-cost science equipment - 'we are not alone'.
- (ii) Gained an insight into the need of in-service science workshops for teachers.
- (iii) The experience of the workshop is directly relevant to my present schedule in the Ministry of Education.
- (iv) Gained some knowledge of life in PNG.

Question 6. What would you plan to do as a follow-up to this workshop in your country?

- (a) In your official capacity?
 - (i) Making recommendations to our home government especially on the need to support a regional centre for production of low-cost equipment.
 - (ii) Setting up of training programmes for science teachers.
- (b) In your professional capacity?
 - (i) Publicizing the outcome of this workshop by writing articles on low-cost science equipment in professional journals.
 - (ii) Organizing Science Teachers' Associations with a view to disseminating information on low-cost science equipment to many more practising teachers.
 - (iii) Exploring the possibility of recommending the bulk buying of science equipment for schools.

Concluding Remarks

This evaluation has highlighted a number of issues based on the response of participants contained in the completed questionnaires.

The workshop can be said to be successful if one examines the extent to which the goals of the workshop have been met. Participants became aware, more than ever before, of the problems and prospects of low-cost science teaching equipment. The need to underscore the applicability of the main concept of low-cost equipment in third world countries was clearly brought out. Of significance is the fact that an awareness in the need to co-operate, be it at regional or international levels, was demonstrated. It is to be hoped that formation of regional centres for the production and procurement of low-cost science teaching equipment will result, and that the day will not be far when children in third world countries will be involved in

'sciencing' - that is being actually involved in doing science - instead of being told about science. That realization can only come if science teaching equipment is available in quantity and in relatively good quality. With the emphasis on low-cost science teaching equipment, even the supposedly poor countries will be able to invest profitably in proper science teaching.

Co-operation among and between member countries in the Commonwealth in the bid to popularize low-cost science teaching equipment is vital. The Secretariat lead paper presented at the workshop pointed out that:

'Already the similarity of problems in science education throughout the Commonwealth regions has confirmed the value of co-operation in this field between science educators in this region, in Africa, in the Caribbean and in Asia. The need to reduce wasteful experimentation where relevant experience and systems are already available in member countries and to facilitate inter-regional travel wherever possible, has long been recognized.'

There is need therefore to publicize the outcome of this and similar workshops.

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LEAD PAPERS

TRAINING FOR THE PRODUCTION OF LOW-COST SCIENCE TEACHING EQUIPMENT

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Introduction

The increasing interest shown throughout the developing world in new science curricula and the local production of school science teaching equipment indicates a healthy desire to make the teaching of science more relevant to local environments and national needs. The interest displayed by Commonwealth member countries in establishing centres for the production of school science equipment can be seen in the extent of the participation in the seminars and other activities on low-cost production of science teaching equipment sponsored by the Commonwealth Secretariat (1, 2) and UNESCO (3) respectively.

There are already a number of production units in existence around the world (4) which could be used as a model for establishing one's own unit. But in any country the one with the greatest chance of success is the one that takes into account such local factors as the educational system (particularly its economics and organization), national industrial structure, availability of small scale-industries, and available manpower. The danger of taking other people's models is that all the factors used in establishing them are pertinent only to that particular country. This point is illustrated well in the brief case studies on four different centres reported in the first of this series of Commonwealth regional seminars on the theme of low-cost teaching equipment.

Whatever system of production is established, a range of skilled and unskilled manpower will be needed. The skills required will range from engineering to administration, from design and production to storekeeping and driving. Suitably qualified staff are of prime importance for the staffing of a production centre, and a full appreciation of their importance can only be obtained by studying the components and operations involved in producing an end product.

However, before looking at the components of a production unit there is a need to clarify the term. The interpretation given by Indge is appropriate here: 'Low-cost', he says, "is a relative term; it must be seen in the specific context of a particular educational system. Low-cost materials successfully developed for one situation may be prohibitively expensive in another. Thus even though in some developed countries, particularly during the last two decades, there have been major curriculum innovations that have not depended on costly traditional apparatus, these innovations have generally failed when introduced into economies which have to work with cents rather than dollars. Low-cost apparatus might also imply alternative cheaper sources of commercially produced items, teacher improvisation or local production. This is immaterial; whatever connotation the term might have, the only important criteria which should be emphasized, in the context of the objectives of this

seminar, is that a particular item of equipment, preferably produced locally to serve the needs of a particular curriculum, is as cheap as possible within a given educational system."

Components of a Production Unit

When considering the production of any item we are concerned with the method of obtaining the end product. To obtain this end product we require the inputs, the production process and the outputs. Under inputs we are concerned with such items as buildings, plant, materials, finance, supervision, labour, management, orders, etc. Under production we are concerned with the manufacturing and assembly of the end product, whilst under output we are concerned with getting the goods to the classroom.

We can break down the production area into a further three basic factors. These are the premises where the production takes place, the people who carry out the production process, and the production process itself. It can be seen, therefore, that the operation of producing an end product - in our case the provision of school science teaching equipment - is a complex business.

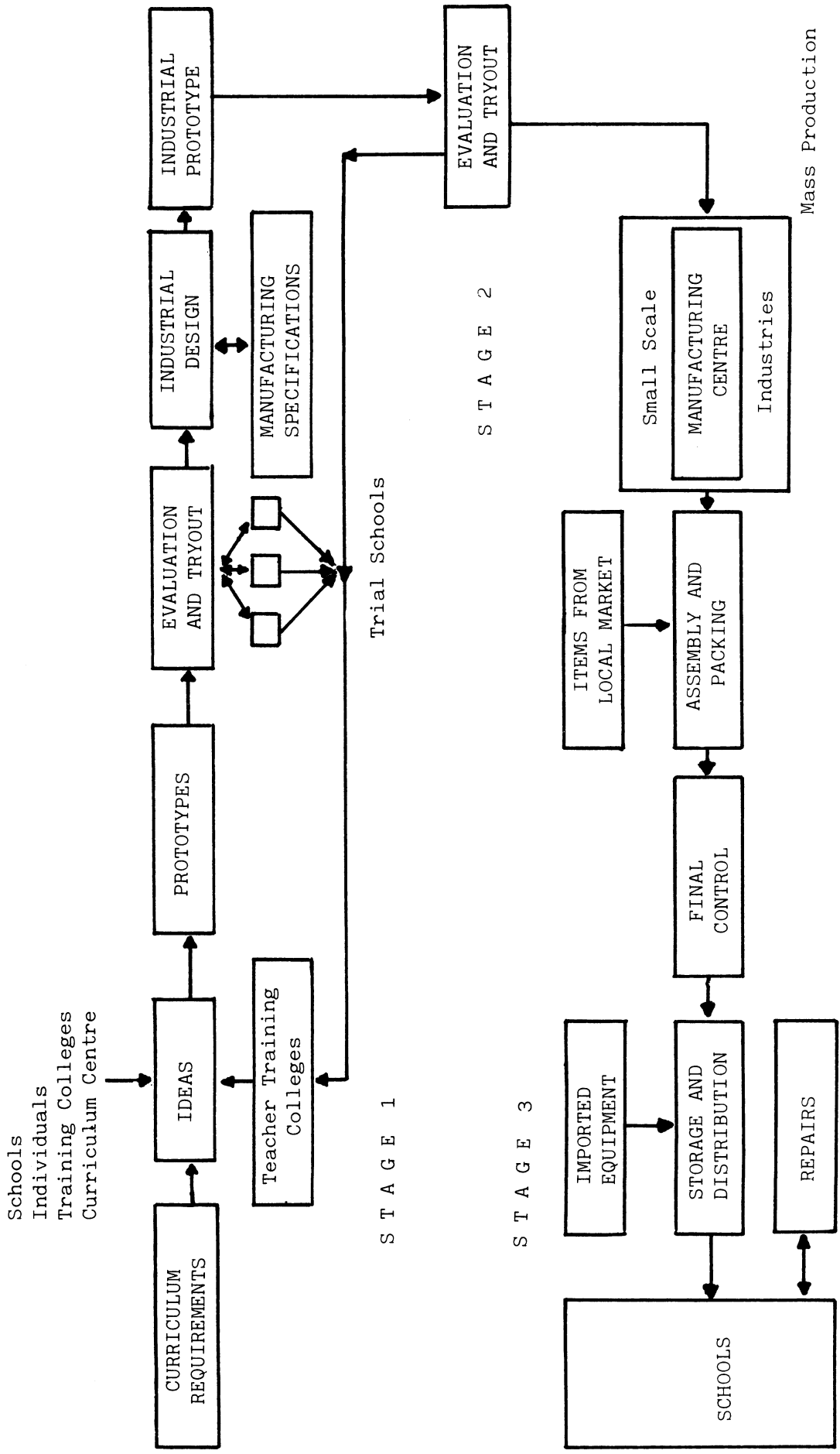
Ignoring at this stage the inputs factor, let us consider the production process and the outputs component. The flow chart on page 38, taken from a UNESCO sponsored seminar, (3) gives an idea of the stages involved in the design, production and distribution of a piece of apparatus.

Using this flow chart as a guide we should first dispel a myth regarding the teacher's role in equipment production: it is a commonly held idea that teachers are the best designers of science teaching apparatus, and consequently the best producers of their own requirements. The fact is that a number of efforts have been made to get teachers or students to produce science teaching apparatus in bulk. Some simple production units have been set up in teacher establishments, including universities, using existing facilities designed for teaching purposes, and in all cases the large-scale production aspect has not been realized. The reasons can be summarized by saying that a teacher can produce a piece of simple apparatus for his own needs after having acquired some basic skills in woodworking and metal-working. To mass produce the same item to an educationally 'student proof' quality requires skills and physical resources which the teacher does not possess. A science teacher's training does not normally involve acquisition of skills related to engineering production.

Nevertheless the teacher's role in the development of a piece of learning apparatus is extremely important since his pupils are the most important beneficiaries. It operates at the beginning when prototypes are being designed and field tested, and at the end when the finished product is being used in his lessons. The intermediate stages of functional design and production are not the teacher's concern; they are the problem of design and production engineers.

To return to the flow chart we can break the flow into three fairly clearly defined stages. The first is the 'ideas' stage when a prototype linked to the curriculum is produced and tried out in the schools. The second stage is the 'production process' during which the final prototype is turned into an 'industrial design' and the item is mass produced. The third stage is the output or 'distribution' stage when the items are collected from the producers and distributed to the user. It is interesting to note that there is a very important appendage to this third stage, namely 'repairs' or 'after sales service'. More will be said about this later, but let us now look at each of the three stages in turn.

SUGGESTION FOR
A GENERAL SYSTEM FOR THE DESIGN, PRODUCTION AND DISTRIBUTION
FOR SCHOOL SCIENCE EQUIPMENT



STAGE 1: THE DESIGN AND DEVELOPMENT SECTION

Curriculum Requirements

The two previous seminars on this theme have outlined the changes taking place in the science curriculum. The changes are mostly towards an inquiry-based approach to the learning of science. An important point mentioned is that 'successful science curriculum development necessitates the collaboration of many educational institutions'. Curriculum units or centres, teacher training institutes, and university education facilities must join forces with teachers in the field to produce material that is relevant both to national educational goals and to teachers working in the classroom.

This is equally true for the development of teaching apparatus which must be related to the curriculum. Equipment production centres therefore require a section which can liaise with the curriculum development groups and develop their ideas and requirements into practical terms.

From the engineering point of view this constitutes part of the market research activity (i.e. the investigations necessary before deciding what article is needed). The questionnaire developed by SEPU to survey the existing equipment position prior to developing material is a good example of part of the market research process. It is shown on page 78.

The Design and Development Section

Examples of the design and development section, and of inputs to it, can be seen in the case studies already referred to. This section should be staffed by qualified, experienced science teachers, qualified technicians in a number of disciplines, and a design engineer. It is most important that the design engineer forms part of the team since, besides being involved in the development of prototypes, he will be responsible for converting the prototype approved for production into a series of mass production components.

The role of evaluation and try-out cannot be over-emphasized. One can still find some 'ivory tower' persons who claim that trial testing is not needed since we know the requirements. It often happens, however, that the more remote we get from the teaching situation the more vague become the memories of classroom practicalities. For this reason the rotation of the teacher component of the development section is desirable. In places this scheme already operates with teachers being seconded from the classroom to the centre for a period of two or three years and then returning to the school system. By operating a staggered system of recruitment, the development section is always staffed both by 'experienced developers' and by 'new boys' who can bring in the up-to-date classroom problems. RECSAM for example, attempts to include in all of its training courses personnel from previous courses, and this appears to provide the necessary continuity.

Evaluation also needs to be a continuing activity. Curriculum projects are often evaluated as they progress. Indeed, some projects employ an evaluator to do the formative evaluation as the development of the material progresses. Unfortunately very little attention appears to be given to evaluating the development of science teaching equipment produced by low-cost production units. More often the 'good idea' is turned into a piece of apparatus, or kit, which is distributed without trial testing as to its effectiveness.

Evaluation, however, needs to be more than formative, for items of equipment will need summative evaluation once they have been in use for a period. This applies not only to apparatus and equipment but also to curriculum and printed materials, especially where commercial interests are involved in their marketing and distribution.

Science equipment manufacturers, either international or national, may decide to manufacture and market items developed locally. The inexperienced teacher who has to order equipment from a catalogue without seeing the item beforehand is open to exploitation and manipulation.

Teacher Training

Much of what has been said so far draws attention to need for effective teacher training. Thus teachers need to be taught how and what to order from catalogues. In countries where a limited exposure to technology exists, the author's personal experience has revealed that teachers apparently have difficulty in 'visualizing' from a page in a book what a piece of apparatus really looks like. (Some work has already been started on investigating what an individual 'sees' and interprets when faced with a newspaper picture or film.)

With the introduction of Nuffield Science and its emphasis on using investigative techniques, a realization occurred that teachers were not being trained to use apparatus in the laboratory in anything other than the manner which had existed for decades. The standard practical exercise requiring some principle to be 'verified', with pupils regurgitating the instructions found in numerous 'laboratory manuals', was the norm. As 'investigative science' curricula were being developed, enthusiastic teachers - often in isolation - attempted to change and incorporate the 'new methods' in their teaching. But the mass of teachers continued as before. So did the teacher training colleges. Eventually a realization crept in that since the 'discovery approach' to learning was with us, teachers would need to be specifically trained for the approach. The assumption that 'of course teachers can teach practical science' was found wanting: teachers had to be taught how to use their laboratory; how to use their classroom as a laboratory; how to let children perform investigations using apparatus; how to programme work over a long term; how to recognize apparatus; how to order apparatus; what to order from catalogues.

In a number of countries a change came about as new teacher training programmes were developed. The Science Teacher Education Project (STEP) (5) developed in the United Kingdom during the period 1972-74 is one example. It is notable that its development was accompanied by a strong recommendation that overseas countries wanting to use the approach should not take it in its entirety (a realization that material had to be locally developed to be effective). The Australian Science Teacher Education Project (ASTEP) (6) is an example of this kind of local approach: so are the continuing attempts to develop similar material in Nigeria.

Many countries still plod on unchanged. A visit to teacher training colleges in many developing countries show that the inputs made, often with foreign assistance and expertise, have stagnated once the 'experts' have departed. (A recent visit to one teacher training institution revealed that even the notices on the laboratory pin-board had not been changed for at least five years!) Lip service is paid to new curricula, but in the end teaching techniques remain the same. Fortunately this seminar/workshop is designed to investigate the problems of training, and another paper will deal

in depth with the training of teachers. Suffice to say that if a country wishes to invest in producing science teaching apparatus it must also invest in teacher training if the investment is to be worth while.

Whatever method is adopted for marketing and distribution, a summative evaluation will be needed. This should best be carried out by an impartial evaluation group, since an evaluation unit involved in the actual development process can easily be biased towards 'proving' the product. In the United Kingdom we have examples of two groups which evaluate science equipment. One is the Scottish Schools Science Equipment Research Centre (SSSERC) based in Edinburgh and financed by the Scottish Education Authority; the other, in England, is the Consortium of Local Education Authorities for the Provision of Science Equipment (CLEAPSE) based on the campus of Brunel University in Uxbridge but wholly financed by member education authorities. Though both primarily examine and assess existing apparatus, they also seek to modify or develop new apparatus or equipment. Close liaison exists between them and equipment manufacturers, and relevant information is disseminated to teachers via regular bulletins and through exhibitions and other activities on 'open days' when teachers visit the centres to discuss professional problems. On a smaller scale it is possible that an evaluation group established within a Science Teachers Association or at a national university would be equally effective.

In looking further at the operation and organization of the design and development section, with its need for liaison, trial testing and construction of prototypes, we find that the centre itself needs to be led by a well respected educator, preferably with a science background, who is able to co-ordinate the efforts of different specialists to provide the most appropriate material for learning. This educator in question must also be fully committed to the need for improvement in science teaching.

A job description for such an individual might read:

- Position: Director of School Science Equipment Development and Production Centre
- Duties: To establish and maintain a development and production centre for providing suitable science teaching apparatus to schools and colleges throughout the country. Besides heading the centre the director will be expected to liaise with all relevant institutions and bodies to bring about an overall improvement in the quality of science teaching with particular respect to the use of apparatus and equipment. The director will, in conjunction with a steering committee, establish specialist panels to assist with the development activities of the centre.
- Qualifications: A university degree in Science and Science Education with considerable proven experience in curriculum development activities and practical educational administration.
- Salary: Negotiable: depending on qualifications and experience.

Since it will be difficult for the functions of the director to be carried out by one person, it is likely that a committee will be formed to assist the director and guide the work of the centre. Such a committee should consist of invited and/or appointed members from across the whole spectrum of

education as well as from outside education. One of the functions of the committee should be to approve the production of successfully developed prototypes. In other words, members of the committee would operate as the Board of Directors of a company. DAYM in Turkey uses this system. And it appears the Regional Seminar Workshop held in Tanzania in 1977 thought along similar lines when it recommended that: 'It is important to establish an institutional framework which will facilitate communication and collaboration across government ministries or departments as well as across educational institutions and agencies, including curriculum development units and teacher training institutions.' Thus, it was suggested at the seminar that a consultative group forming a consortium of relevant institutions might serve as a useful resource for the production unit. Such a group should include curriculum developers, practising teachers, representatives of those government ministries with direct interest in education, teacher training colleges and science teacher's association. 'On the matter of this committee it concluded by saying' ... the consultative group envisaged should be involved not only in initiating the production process but also in evaluating the finished product'.

When budgeting considerations are being made for the production centre, special attention needs to be given to the design and development section. Since the section is concerned with making and trial testing apparatus flexible budgeting arrangements are needed for travelling and per diem allowances, as well as for procuring materials. Ease of local purchase is essential for a development operation. A delay of a few weeks in obtaining a box of screws or a packet of solder brought about because the centre has to purchase everything through a government ministry is sometimes a great stifler of enthusiasm. A centre which has its own accounts section can overcome this stumbling block.

STAGE 2: THE PRODUCTION PROCESS

Industrial Design and Manufacture

In Stage 1 we referred to the industrial designer as the man responsible for turning the prototype into a mass produced entity. Whereas the educators are the link to the consumer, the industrial designer is the link from development to production. It is at this stage that the teacher plays a passive role. He will be asked to trial test the pilot production model before it is mass produced, but if the designer has been functioning properly during the prototype stage, very little difference should exist between the finished prototype and the production model or the end product. It is likely that the difference will be 'cosmetic' rather than functional, that is, only in choice of suitable materials, colour, scale, etc.

The design team will probably consist of the team leader (the design engineer) and draughtsmen who are capable of preparing the detailed working drawings. Once the team have decided upon materials and operations, the item will be 'costed', that is, an estimate of the production cost will be made. This estimate will include such details as cost of new materials, any special tooling needed, any sub-contract work to local industry, labour charges and so on. Once this has been carried out, final approval for the go-ahead to manufacturers may be sought from the policy-making committee. This approval will generally be a rubber stamping operation since the original approval to develop the article was given before the development stage (i.e. during the initial market research). At this stage the factor of most importance is the provision of adequate finance to manufacture the article.

Another individual who is involved with the design team is the production engineer. As head of the production process his experience in programming work through the various workshop facilities is utilized in order to integrate the new item into existing production schedules. Besides programming he will also assist with the advance procurement of the necessary materials needed to make the components; he will also indicate which items have to be sub-contracted out for manufacture by local industry.

The report of the regional seminar in the Bahamas indicates that the NCERT in India utilizes some twelve commercial manufacturers which tender for the batch production of certain items for inclusion in the kits. These suppliers work to the strict requirements of the workshop department.

In the case of sub-contracting, the standards of quality must be maintained, and it is essential to have within the centre a quality-control group who carry out a regular sampling of products from within the centre as well as items (either parts or whole units) purchased from outside. This group will most likely form a component of the production process functioning under the directives of the head of the production process.

The Production Facilities

Having completed the process of turning the original design sketches into working drawings for the use of the various sections of the production workshop, a number of steps have to be taken before any components can be manufactured. An important area is one involving 'tooling'. This is the process of making any necessary dies, moulds or jigs for, perhaps, plastic injection moulding, castings, press tools, automatic lathes, and so on. The degree to which this will be needed will depend upon the object to be made, the number required, and whether the production process is to be labour intensive or capital intensive.

The following examples of the components of a production workshop at the NCERT is taken from a paper presented by Mr. Bhattacharyya at the regional seminar held in the Bahamas in 1976.

"Once the design has been worked out, the design office makes the drawing of the approved model with complete technical specifications. The drawings are then passed on to the production section for batch/mass production through the production-planning and control section. The various functions of the Centre producing low-cost science equipment are as suggested in the diagram. With expert advice from the Centre, the States draw up their plans and arrange for the necessary fund to meet the equipment needs of schools over a specified period. A region which does not have any local industries may prefer to request the Centre to undertake the mass-production for them, whereas a region located in the industrial belt may prefer to get the equipment manufactured locally with or without modifications as shown by the dotted lines in the diagram. The Centre can provide the design specification and necessary information for them. In addition, the State may ask the Centre to train their technical staff in the inspection and quality control aspect of equipment production".

Workshop Staff

The workshop department has approximately 100 members of staff and, depending upon demand, also employs a daily labour force as required. The following

SUGGESTED ACTIVITIES OF THE DESIGN,
PRODUCTION AND EVALUATION CENTRE AT THE NATIONAL LEVEL

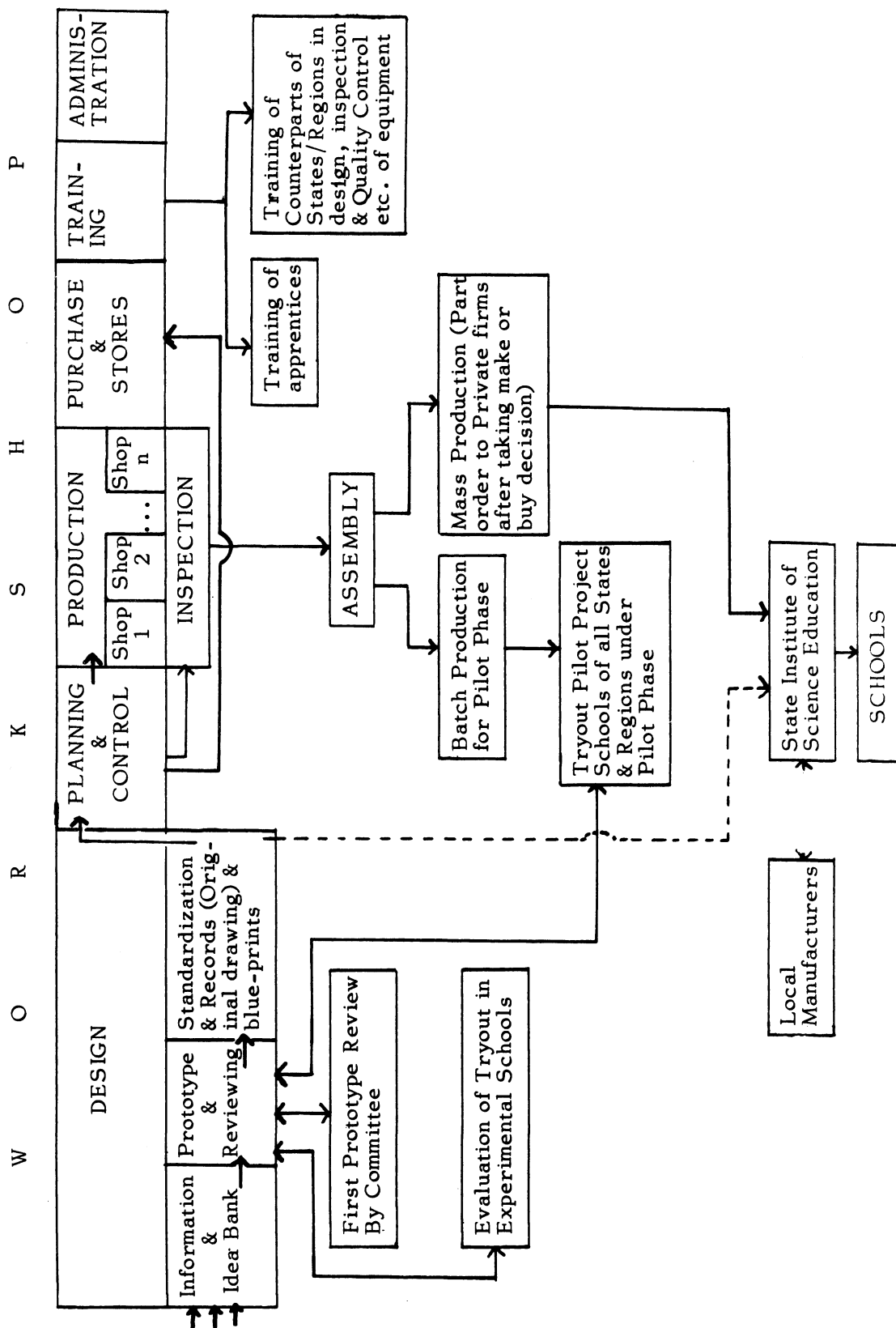


chart outlines the structure of the staff, but a particular title does not necessarily reflect the actual duties of the individual. For example, of the technical officers, one is responsible for office administration; in the fine mechanic grade, two are in the packing section.

Head of Workshop Department

Principal Assistant

Technical	Stores	Administration
Technical Officers (5)	Assistant Stores Officer (1)	Office Superintendent (1)
Foreman (1)		Assistant Superintendent (1)
Junior Foreman (4)	Senior Storekeeper (1)	Upper Division Clerk (1)
Senior Draughtsman (1)		Lower Division Clerk (2)
Junior Draughtsman (2)	Junior Storekeeper (2)	
Senior Laboratory Technician (2)		
Fine Mechanics (15)		
Mechanics (42)		
Peons (General Staff, e.g. messengers) (17)		

Daily Labour Force

Recruitment of staff is done through national advertising, and the successful applicants are appointed to their appropriate grade and duties. A system exists whereby any individual who shows aptitude can apply for the relevant trade test and be upgraded.

The foregoing provides a concrete example of the sections contained in a production unit; the machinery required for its particular role is as shown on pages 79 to 82.

Not all productive units are as large as the example given; generally they are much smaller, since their size is appropriate to the market. For example, in India there are some 452,000 primary schools (the school level for which the production unit was producing apparatus in 1976). A country with, say, 100 secondary schools and about 2,000 primary schools would have a much smaller unit. An example here would be, say, Papua New Guinea. Here it might be possible to set up a viable organization to produce apparatus using a workshop staff of about 10 persons working with a curriculum development group who generates the 'ideas'. Such a production unit might make use of daily recruited staff to meet its extra requirements when a bulge of work is passing through the workshops. Such a facility highlights a need for a flexible budgeting arrangement which can hire extra personnel when required.

In referring back to the staffing structure of the production unit shown on page 3, we note that a variety of skills are needed. The training of skilled personnel is less of a problem in countries which have an industrial base to build upon. They have technical colleges and trade schools

to provide individuals with some of the necessary training. Further specialized training will of course be needed in some fields, as for example, plastics work where the manufacture of the dies is a skilled process. There is a strong argument for regional co-operation when it comes to the use of plastics and the dyes required. One consideration is the compatibility of machinery which would facilitate the interchange of dyes between countries. Another consideration is the material from which the die is made. A dye made for a production run of 100,000 units would need to be made of tougher material than one required for a 1,000 units. This pre-supposes that one country produces similar items to another country. Although this has not yet been qualitatively surveyed, a look at a number of countries indicates that there are similarities, and basic items such as test-tube racks, stands, and clamps, etc. with only minor differences which could probably be standardized to one design (perhaps requiring regional co-operation). In using plastics one requires some new skills, whereas in using indigenous raw materials it is likely to find personnel already skilled in their use, such as local craftsmen. The employment of such persons would naturally require considerably less investment in training. More will be said about this later.

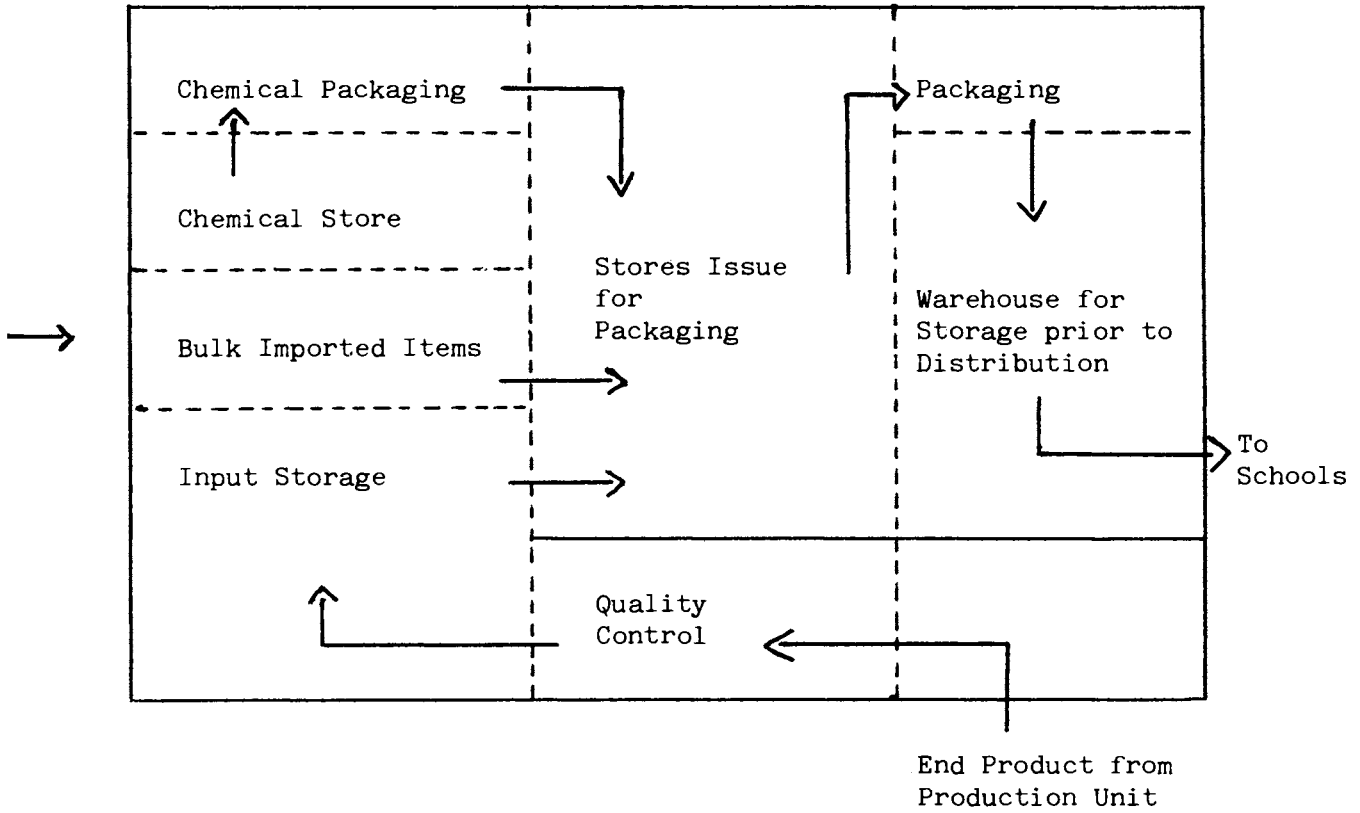
STAGE 3: STORAGE AND DISTRIBUTION

The basic facility for this stage is a well-designed space. The function of the stage is to receive from the production process a series of items which have then to be stored, or assembled into kits and then stored, for onward distribution to educational institutions.

Although the production unit will have storage space, this will be concerned mainly with raw materials and parts for assembly of the end product as well as for tools. If, however, the final products from the centre are going to include items imported from abroad, for example chemicals, then the storage area becomes a little more complex since it requires a section which can take the bulk purchases and package them according to individual school requirements.

Mention has already been made about purchasing parts for assembly into a piece of equipment or whole pieces of equipment from the local market. Local purchase does not have to stop there. When looking around a village bazaar one finds a variety of expertise ranging from cloth dying through pottery to gold smithing or similar arts. In both cloth dying and pottery, chemicals and dyes are used to either colour the cloth or glaze and decorate the ceramics. Often these chemicals and dyes are obtained locally from natural resources. No doubt there are natural resources that could be used by the centre, perhaps by stimulating a local co-operative or trader to supply them and thus reduce the number of items imported from abroad. Besides, schools usually require only small quantities of such materials at any one time, and the supply may therefore be well within the capabilities of a small trader. The trader could probably package them into the right quantities for schools and so avoid further re-packaging at the centre. (Quality control is important if this method is to be used.) In island communities spread over a wide area one can find many techniques, originally developed for survival, which would be utilized by the centre for the benefit of schools. For example, the use of particular leaves of plants or trees for dyeing or medicinal purposes; substitutes for ropes and string; liquid containers from bamboo, and so on. An investigation of local resources is an important (but often overlooked) part of the initial planning of many centres.

FLOW PATTERN FOR STORES



From the flow diagram on page 38, we see that items from the local market are fed into the production workshop. One reason for this is that they are then fed into the store through the inspection department either as parts of the finished product or as individual items in their own right. The diagram on page 3 indicates a flow pattern for the store, indicating some of the sections which may be needed in a store.

The location of the stores should be in close proximity to the production unit to reduce handling and movement to a minimum. However the final storage in the warehouse does not necessarily have to be integral with the other components and could be located in a separate building depending upon the distribution methods to be used. For example, a ministry of education might already have a warehouse for other educational materials, such as paper and writing materials, and it might be desirable to store the finished produce from the centre in this store so as to integrate them into the existing distribution system.

Particular attention needs to be paid to packaging and distribution, since it has to be remembered that the final destination of the output from the centre may be a week's travel over bad roads. Roads, though, are not the only transportation problem. Island and river communities may have problems related to water transport. To deliver equipment to these communities, packaging requires particular attention. The effect of sea water, corrosive atmospheres and humidity, as well as the complete immersion of a package in water, may have to be considered. An unseen hazard is the reaction of one or more chemicals if sea-water seepage occurs. Again, the packages will probably be handled a number of times by unskilled, sometimes illiterate, labour on route. Packaging, therefore, must be properly done to prevent breakages and deterioration from the environment, factors to which too little attention is paid.

When considering distribution to schools, one has to weigh up the alternatives. Some questions that should be answered are: Which are more reliable, local or national carriers? Is it more economical to distribute by commercial hauliers or to have a fleet of vehicles belonging to the centre for this, and other purposes? With this latter possibility in mind, the procurement of multi-purpose vehicles would give flexibility to the centre's operations, remembering that materials need to be trial tested (hence distributed) during development. In addition, staff need to be transported during trial testing (and also during in-service training work), and the repair and maintenance section needs transport to operate effectively. We need to be warned that using a central pool belonging to a government ministry is often not advisable due to possible non-availability when actually required.

To conclude this section, the important point is that the finished products from the centre should not be left for long periods awaiting distribution from the warehouse. The aim should be for a quick turnover. The period spent on the shelf in storage means that children somewhere are receiving second-rate education and the capital investment in the end product is being wasted.

Repairs and Maintenance

Any investment in apparatus and equipment is wasted unless consideration is given to the regular maintenance and repair of broken items. The instances of apparatus lying around in schools for want of some simple repair are appalling. Unfortunately this problem appears to increase as countries receive equipment under various aid programmes.

One of the ramifications of providing any piece of apparatus or machinery is 'return on investment' or in other words the working life of the item. If an item is broken during distribution, the effort and cost of producing it has been wasted. Similarly if the item breaks down due to neglect, the original investment has been lost. No education system can afford to waste money since, in the long term, it is the national development of the country which will suffer through the lack of relevant educational facilities.

Repair and maintenance services should therefore be seen as linked to the production and distribution process. The facility required for this section is a small workshop in fairly close proximity to the production workshops, enabling easy access to spare parts and shared use of some resources so as to avoid duplication. As previously mentioned the repair and maintenance section will require transport to visit schools for on-the-spot repairs, as well as for collecting and delivering items which have been repaired in the centre.

The skills required by the personnel who will staff this section will be basically engineering ones, with some degree of specialization depending upon the sophistication of equipment in the educational institutions. If specialization is necessary, this is best provided within the country as on-the-job training. This will encourage the trainee to develop ingenuity in tackling problems, and in making good use of simple tools. Training given abroad (e.g. at the place where the equipment is manufactured) exposes the trainee to a variety of specialized tools and test equipment which he cannot expect to find in his normal day to day work. Naturally, if the centre is to produce fairly sophisticated apparatus, its staff must be trained in the specializations involved, and training may have to be given abroad. On their return these individuals can be used to train the repair and maintenance personnel and to provide back-up expertise when required.

An example of the inadequacy of teachers and their limited knowledge of equipment can be seen from the experience of one centre which was asked to examine some new balances reported as being 'broken on arrival'. In examining the balances it was found that the clamps fitted for transportation purposes, and which locked the mechanism, had not been removed. The instruction manual was available but the teachers in the school had not been able to appreciate (and locate) the clamps. An additional problem was that the balance required an electrical supply to illustrate the optical scale, but the school only had electricity in the evenings, outside of school hours. The repair and maintenance team were travelling with their own vehicle which had its own petrol-driven portable generator and so the setting up and operation of the balances could be demonstrated and tried by the teachers. Two points are highlighted here - the support the teacher needs, and the type of equipment which a repair and maintenance team may need.

Mention has previously been made of local resources, in terms of chemicals and equipment. Expertise is another local resource which can be exploited. The village jeweller may be able to repair some apparatus as may the 'clock doctor' and radio repair men.

There is much that a teacher can do to keep his equipment and apparatus in good order, but he has to be taught what to do and how to do it. This does not mean that he has to become a trained repair man in addition to being a teacher. It means that in understanding how to use equipment, he will be concerned with setting it up, checking it regularly for serviceability, and knowing when to call in the specialist to correct something what has gone seriously wrong. The provision of adequately trained school science laboratory technicians will, of course, allow the teacher to be relieved to a great extent of the maintenance and repair responsibilities.

APPROPRIATELY TRAINED PERSONNEL

Overseas Training Considerations

The specialization required by the staff of an equipment production centre are not generally found in employees of a ministry of education, except in technical institutions. So to obtain the individuals with the necessary skills one has to look for persons employed in industry. Often, however, the scales of salary within government service are unattractive and the recruitment of skilled personnel to the government service is not possible. In these circumstances the provision of specialized training for selected individuals is necessary. In many instances, this training has to be given overseas where the particular specializations are an established factor. All too often such training is given to the wrong people, for the wrong reasons, and for far too short a time. Consider, for example, a workshop technician whose work it is to produce the dies for a plastics injection moulding machine. Local recruitment may obtain someone who has been trained in the use of workshop machinery at a technical college. It is most likely that his knowledge of materials will not extend far into plastics materials. His recruitment has probably been undertaken by non-technical personnel. The individual concerned may then find himself in a situation where he is expected to produce dies to close fitting tolerances using techniques of toolmaking for which he has little training.

Because he is a member of the technical staff, the priority for fellowship training for periods of two years or more is low, since it is often accepted that 18-month to two-year programmes are intended only for "academic study". Yet the training may involve his being attached to a manufacturer where instruction will be given in the use of certain machinery, or it may involve attachments where particular manufacturing skills could be developed. Unfortunately at the end of such training there is no academic certificate awarded and no advanced qualification obtained. Yet, unless the technical skills in whatever discipline needed, are available to provide the base of operations, any investment in "academic" education is lost since there is no one to put into practice the theoretical design.

Local Recruitment Considerations

The recruitment of staff does not, of course, have to rest with looking for personnel already trained. After establishing a suitable nucleus of capable personnel it is possible to recruit unskilled personnel and train them in specific tasks. In many ways this approach has much to commend it. Whether production of apparatus and equipment is capital intensive or labour intensive, most of the time the work is repetitive. By recruiting semi-literate labour and providing the training in the particular skill required, the centre is likely to be more efficient since it provides regular work for persons whose expectations from life are not unnecessarily too high and hence the centre may not suffer from the unrest and dissatisfaction often brought about by employing an over-trained individual for routine mundane tasks.

It is worth pointing out the need to attend to ergonomics as a cost and training factor. If the traditional method of, say, working with sheet metal is at ground level rather than working higher up on benches where the feet also may be used, then this factor should be taken into account when providing the facilities to be used. If the labour force is to be recruited from the village where the individuals may have already been working with sheet metal making bowls, stoves, cooking utensils, etc., then, by matching the traditional facilities, less re-training would be needed, with the attendant reduction in

costs. In the situation where small-scale industries are to be used to manufacture apparatus, particularly if they are to be set up as part of a national development plan, then the traditional methods of working should be the foremost criterion for consideration when deciding what support material is needed to establish (or improve) the production unit. The establishment of small-scale industries is very pertinent to island communities and should receive particular attention when considering the establishment of a production unit.

What to Make and Where to Use it

To conclude this paper we need to think about what the centre is going to produce - kits of apparatus, individual pieces of equipment, or both? Naturally, this problem will have been resolved during the initial planning stages for the centre after the appropriate "market research" has been carried out.

We are, unfortunately, conditioned to have a "laboratory" to teach science in. Fortunately this idea is breaking down in some countries where new curricula for primary and early secondary schooling are tending to deal with science as a whole and not as artificially separated disciplines. Life itself is a laboratory - the place where things happen. Life occurs both in the school and outside of the school, hence the need for a specific area to be used as a laboratory is questionable, perhaps even undesirable in a primary school. The classroom and school compound make an admirable base for practical science learning, but consideration needs to be given as to where and how apparatus should be stored when not in use. Here the self-contained topic kits with their own storage containers have an advantage. Whatever the case, the teacher needs training as to how to use the learning facilities available, be it a classroom or a class under a tree (what better environment to start learning about science!). Since this is the topic of the next paper I shall conclude by quoting an old Chinese proverb: I hear, I forget; I see, I learn; I do, I understand.

There is no substitute for "doing".

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LOW-COST SCIENCE TEACHING EQUIPMENT: TRAINING FOR USE

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Introduction

One of the problems in present-day education is that most educators and laymen cannot visualize, and therefore cannot explain, what is happening during science lessons in our schools. If you ask any science educator (not a science teacher) or a science education officer to describe accurately the kind of science education taking place in schools, you are likely to be given a list of textbooks in use and a copy of the science syllabus. If you then enquire about science equipment, you may well be offered an inventory list and very vague generalities about the extent and style of its use. The science teacher should know whether the equipment is used regularly, but no one will know how effectively it is being used.

This lack of knowledge about the kind and quality of science teaching offered in schools can be linked with a variety of other issues which together comprise the general problem of science teaching. Some of these issues are the quality of teacher training, the infrastructure (e.g. laboratory assistants), the degree of importance placed on science education, and the cost and availability of science teaching equipment. It stands to reason also that if the equipment is not suitable or relevant to the needs of the lessons (e.g. if it is too specialised or too cumbersome) it will probably not be used.

The problem of cost has been the subject of at least two regional Commonwealth workshops and need not be dealt with here. Nor need we deal with questions relating to the training of laboratory technicians as these are the subject of another paper at this workshop. What does need to be stated is that the knowledge and skills associated with production and usage of low-cost science teaching equipment are as essential for the science teacher as for any staff without science qualifications who are connected with the teaching of science. In addition, the importance attached to science education by a school can be a critical factor in school administration in a variety of ways. For example how much of the budget is allocated to science teaching, and how much administrative duty is assigned to science teachers, are two of the indices of the actual degree of importance placed on actual science teaching no matter what official policy statements may say.

These aspects are mentioned only in passing in this paper. This does not mean that they are of minor significance; on the contrary they are vital issues in the improvement of science teaching and if we ignore them we shall be restricting our vision unduly.

The Issue of Teacher Training

In most cases the training of prospective science teachers is shrouded in general course descriptions which convey little more than that the students are taught a number of science topics (in non-university institutions) or are learning academic science (in universities). This is the general problem of which training in the use of low-cost science teaching equipment is only a sub-set. That is so because at the professional level, effective use of low-cost science teaching equipment - assuming it is available - is related not only to its own inherent characteristics but also to the teacher's understanding of science, his ability to relate to learners, and his perception of his role in the learning of science. The training of teachers in the use of the equipment, therefore, cannot be separated from the general issue of science teacher training.

Understanding Science

One of the most important objectives of science is to promote understanding of certain phenomena. Science does not, of course, end there because of purposes of understanding are varied. They include developing still newer understanding, being able to explain observations, applying knowledge to solve other problems of interest, and so on. What is of paramount importance, as one of the most outstanding modern physicists, Jerrold Zacharias (1968, p.144) has said is... "the experience of understanding even though it be about something seemingly trivial, something simple, something not very deep, is enough to content us momentarily. We feel that one has to understand something simple in order to learn the nature of understanding itself." But it should be added that "simple" is not synonymous with "trivial" or "easy".

The notion of direct experience in learning science is central in a good science education. It also is supported by findings in other fields. Piaget, a pioneering researcher in cognitive development, has observed that "words are probably not a short-cut to better understanding. Mainly, language serves to translate what is already understood." One has to experience the profound feelings when the same answer comes up in apparently dissimilar events in the science laboratory or when one sees a thick precipitate form upon mixing two liquids. No words can convey those feelings of joy and of understanding of what actually goes on.

In science one works from specific cases to generalizations: it is the specific cases that furnish experimental bases. This means that one abstracts some part of our complicated world on the basis of a variety of factors, on the basis of "tools" of science both tangible and intangible. Included among the tools are scientific theories, laws, and knowledge; language to express and communicate with clarity (measures, graphs, etc.); sight, hearing, etc. and their physical extensions (such as microscopes, telescopes, earphones, and a whole variety of artifacts that comprise science learning equipment). What is of significance is that the use of each tool, whether simple or complex, is associated with an abstraction; it is a purposeful decision based on a perception of the tool's utility in a given situation.

Learning to perceive something as a tool is at the core of learning to use it. The words are those of the late Michael Polanyi: "It implies that a useful purpose can be achieved by handling the thing as an instrument for that purpose. I cannot identify the thing as a tool if I do not know what it is for - or, if knowing its supposed purpose, I believe it to be useless for that purpose... if I come across a tool of which I do not know the use, it will merely strike me as a peculiarly shaped object." (Polanyi, 1973, p.56). It

follows then that if a teacher views science in theoretical terms, low-cost science equipment will not be viewed as a tool. If viewed as a series of exact laws, low-cost equipment that aims at giving only an order of magnitude will not be viewed as a tool. The extent and style of usage of science equipment depends on one's view of the scientific enterprise.

The Nature of the Learner

The learning of science is essentially a participatory activity, but the activity should be in consonance with the learner's stage of development - physically, intellenctually, and psychologically. Training teachers to make effective use of low-cost science equipment should not be divorced from training them to understand young people's characteristics because a mismatch between learner and equipment can have disastrous effects on their desire to understand science or to choose a career in science.

The physical characteristics can be quite obvious, and teachers should make allowance for them when deciding on the equipment ot be used. Heavy pieces and intricate assembly procedures should be avoided in classes of very young children. Also, components which can be injurious to students (e.g. cutting equipment) should be used under a teacher's close supervision.

A teacher's insensitivity to students' learning needs in the development of motor skills can create problems. Very often teachers expect students to be able to assemble apparatus without prior practice and in a short time! If students do not succeed, or become discouraged, or take too long, or break something, as often happens when students are learning to use microscopes, teacher may become reluctant to let students use the equipment. Such clumsiness may be due entirely to a mismatch of equipment with students' level of motor skills development. In their science education, and especially in their training to use low-cost science equipment with students, teachers could learn about the manipulative skills required to assemble apparatus. For example, a teacher ought to have some idea of the level of muscle control involved in assembling and using a sensitive weighing balance, in the use of dissecting instruments, and so on.

Even if they can manipulate the equipment quite well, students must teach a certain level of cognitive development to appreciate the function of the equipment and the meaning of its behaviour. Thus, primary school children tend to view events in competitive terms which one is faster, or bigger, or more colourful, and so on. "Ties" or equalities do not count (Hein, 1979); if in a class of 30 pupils the three top students make the same score on a test, "there is no number one". Also, there are no margins of error or "confidence bands" - a one millimetre difference in measures of a line one metre long is as "serious" as a five centimetre error. Yet science looks constantly for similarities and equalities so that inequalities can be treated as special cases. Science thrives on probabilities or margins of experimental error. Science equipment is based on those premises. But primary school pupils can take ten readings of a measure and disregard seven of them if they are the same, and concentrate on the three that remain. A teacher can, of course, correct the students but cannot expect to convince a single one of them.

secondary school students are just as idiosyncratic. Research on cognitive stages of development demonstrates clearly that intellectual development goes through definite stages. For example, at the age of 11, many young people cannot argue from hypotheses to obtain general laws; the stage of formal operations (organization and control of variables mentally and systematically) is not reached until adolescence.

It seems clear, therefore, that the training of teachers in the use of low-cost science teaching equipment should include ways of grading the course along the students' intellectual dimension. Teachers need to be made aware of the stage at which learners are intellectually ready to accept the results of experiments undertaken with certain types of science equipment, and also when the equipment itself can be a source of unexpected learnings arising from direct confrontation with relevant, real, concrete, and varied puzzles associated with practical science investigations. The teacher's role, to borrow Philip Morrison's words, is to mix and to correct, to provide the tissue of science as a whole, and to let mental preparedness grow sharper as the young person experiences the "culture" of science.

Quite often it is not fully realized that primary school children (and in many cases their teachers also) are afraid to handle science equipment. Students at the lower secondary school level can also suffer from inhibitions in the handling of science learning material. This factor is mentioned here to alert those involved in the training of science teachers, because the fear may stem from lack of knowledge of how a particular piece of equipment "behaves," (i.e. whether it can injure the person using it). A knowledge of the components of the equipment and their functions is very useful in reducing such fears. Frequent handling under non-threatening supervision can also bring about re-assuring familiarity with the equipment.

In Kenya there is a science teacher training programme which aims at eliminating these fears and at promoting the use of low-cost science teaching equipment. The Science Equipment Production Unit (SEPU) trains prospective and serving teachers in the use of workshop equipment such as saws, planes, cutters, etc. to make very simple pieces of apparatus. The aim is to make the learners familiar with the use of workshop equipment under supervision. Later, learners are given opportunities to use low-cost science kits made by SEPU, to read and follow assembly instructions, to use the equipment for science learning purposes, and to eliminate fears by becoming familiar with the equipment.

It is not essential to have a science equipment production unit before teachers can be trained in the use of science equipment. In Botswana, for example, teachers learn to design and use science teaching equipment as part of a general course on the construction and use of teaching aids. Students learn to construct simple science teaching equipment and build a kit which becomes their own property at the end of their training. As they enter their careers in teaching, they have simple science teaching equipment they can use from the outset.

In secondary school situations where there are no laboratory assistants, students can be responsible for preparing and looking after laboratory equipment. By taking turns each student can get an opportunity to perform these functions. This practice will help not only to promote the use of scientific equipment, but to create the correct impression among students that learning to handle equipment is an integral part of learning science and that this should not only be left to those who are going to be laboratory assistant.

Contributions of Science Education Improvement Projects

Throughout the Commonwealth there are numerous integrated science teaching projects which provide a great deal of information for the teacher on the use of science teaching equipment. Some of those projects also specify science teaching objectives much more clearly than science textbooks do. The nature of science objectives for example include:

- (a) Simple cognitive skills (recall, comprehension and application of concepts).
- (b) Process skills (ability to observe, measure, classify and predict).
- (c) Attitudes and values (honesty, open-mindedness, constructive scepticism).
- (d) Skills appropriate to science (ability to manipulate apparatus, to construct and interpret tables, charts and graphs, and to recognizing relevant information).

The projects also include considerations of the nature of the learner and of the social and cultural milieu.

Projects such as those for Basic Science, Physical Science, and Biological Science in Fiji have developed laboratory equipment and manuals, slides, and models as an integral part of science learning activities. Their specific objective is "to give emphasis to basic concepts and active engagement in practical work. To design experimental work in such a way as to enable the work to be done with simple, inexpensive and unsophisticated apparatus". A project in Malaysia emphasizes "learning science through activities and practical work rather than chalktalk, textbook memorization or cookbook experimentation." Singapore's Lower Secondary Science Curriculum Development Project also requires learning experiences, simulations, slides and filmstrip viewing. Other projects, too, are worth close examination. Examples are the Secondary Science Project (Papua New Guinea) and the Solomon Islands/UNESCO Primary Science.

The Role of Science Teachers Associations

Science teachers associations in the Commonwealth can play very significant roles in promoting the use of low-cost science equipment. They can introduce the equipment during in-service workshops when teachers are introduced to current ways of teaching science in the schools, in preparation for science fairs, and through newsletters on the use and improvisation of low-cost science teaching equipment.

Workshops for in-service teachers are a very useful vehicle for encouraging the use of science teaching equipment especially where adult and continuing education services are inadequate - and that is almost everywhere in the Third World. At these workshops teachers get the benefit of the experience of other teachers in teaching science in a practical way, they interact with resource staff who are specialists in the design and use of low-cost science teaching equipment, and they get practice in the use of the equipment. Whenever a science teachers association plays a leadership role in a workshop, a variety of resources can be obtained more readily from regional teachers organizations, from the Commonwealth Association of Science and Mathematics Educators, or from the International Council of Associations of Science Education (ICASE); it may also mean that the workshop is not an isolated event but an on-going effort by teachers to upgrade themselves.

A significant mechanism for encouraging and training students and teachers in the use of low-cost science teaching equipment is a science fair. In many parts of the Commonwealth students carry out practical experimental projects based on some aspect of the local environment, for example, the extraction of natural dyes for use on fabrics. Students, with the help of the

teacher, design the experiments, design and construct the necessary equipment, and carry out the scientific investigations to draw practical conclusions. These projects are presented and displayed at school science fairs organized for the purpose and are judged on such criteria as their originality, practicality, and usefulness. An emphasis on the use of low-cost equipment by judges at these fairs can go a long way towards encouraging teachers and students in the use of that kind of equipment.

Science teachers associations can promote the use of low-cost science teaching equipment by describing in their newsletters how to design and construct some pieces. They can also provide teachers with sources of ideas (e.g. the UNESCO Sourcebook for Science Teaching) on the types of low-cost science teaching equipment and on how to use it.

Training in Handling Low-Cost Science Teaching Equipment

Assuming that the pedagogical issues raised above are incorporated in teacher training programmes, there are practical aspects of handling science equipment for its effective use. There are general principles to bear in mind:

Teachers ought to be trained using the same type of low-cost science teaching equipment that they will encounter in school. There will, of course, be additional, more sophisticated equipment "to enable the teacher to gain more knowledge and to discover other ways and means to demonstrate or teach a particular subject matter."

Science teacher training programmes ought to include a course on the design and fabrication of low-cost science teaching equipment. Because of practical difficulties, the objective would not be so much to train teachers to be draftsmen or specialists on the design of such equipment as to help them know how to read and follow the manufacturers' drawings and instructions that usually accompany pieces that have to be assembled before use. However, such knowledge would also enable teachers make decent drawings from which local craftsmen could make pieces to replace lost or broken parts of a kit or even to supplement available equipment. It hardly needs saying that this knowledge is very useful for science teachers because there are often no laboratory technicians to carry out minor repairs and the technicians who do exist lack the skill to do this particular sort of work.

Stages in the Training Programme

Training in effective use of low-cost science teaching equipment should cover four phases: introduction, familiarization, practice, and transfer to other people. Before examining each stage, it is well to bear in mind that skills cannot be fully accounted for in terms of their particulars. For example, we can examine a chemical balance and note its various parts (the pans, the beam, pointer, reading scale and so on); we can go further and describe the steps to be followed to find the weight (mass) of a substance by placing it on one of the pans of the balance while weights are placed on the other until the pointer swings evenly. We would be dealing with the particulars of how to weigh an object. But to be skilled in the use of the balance, one must know the meaning of the behaviour of the balance - how much reliance should be placed on it, how quickly one can obtain accurate results, and so on. All these are parts of the skillful act of using a chemical balance but some of them can be accounted for only in terms of the person using the balance, that is in terms of what the experience of using a chemical balance conveys to the user. Thus, most of the learning of skill is achieved by a combination of example, direct participation, and some formulation of steps to be followed.

Introductory Stage

An "early" education in the use of low-cost science teaching equipment needs to allow wide exploration by the learning teacher. As pointed out elsewhere (Dyasi, 1978), "early" means the stage of cultivating the "aesthetics" of the materials, of allowing the learner to create an affinity for and a familiarity with the material. He can examine the basic tools in a woodwork and metal workshop - touch a hammer, a saw, a plane, piece of wood, and a variety of other items. He might even examine completed kits and take them apart to see what each piece looks like. He is not limited to any particular equipment; on the contrary he might be encouraged simply to explore as much as he wishes.

It is during this stage that the learner develops a rough "map" in his mind about his growth in the use of the equipment. He interacts with orders and expresses his feelings and thoughts to the educator to find out the latter's expectations, but only in a general sense. It may be well to follow Kenneth Grahame's Water Rat:

"Nice? It's the only thing," said the Water Rat solemnly, as he leant forward for his stroke. "Believe me, my young friend, there is nothing - absolutely nothing - half so much worth doing as simply messing about in boats." (Quoted in David Hawkins, Messing About in Science.)

This stage is a recapitulation of the history of technology itself where many practical inventions were preceded by aesthetic uses (Smith). The making of necklace beads, and the shaping of jewelry and sculpture marked the beginning of metallurgy; wheels first appeared as toys; the lathe was developed to turn guilloche snuff boxes long before it was used in heavy industry; and "rockets for fun came before their military use or space travel."

Important as it is, this stage is very often omitted resulting in a failure to generate closeness between the learner and the science equipment. But when a craftsman has no love for his tools, craftsmanship seriously is impaired.

The Stage of Familiarization

The teacher trainee is expected to become familiar with specified science teaching equipment and with its uses. He learns its handling properties and variations in its described as well as unstated "behaviour". This is the stage when the learner tries to make the equipment do what the educator says it can do; he may need the educator to demonstrate aspects of its use, and he may need to observe a style of putting together because instruction sheets never convey that. The learner at this stage will begin to know the equipment personally when he makes it perform a function.

This stage can take a long time depending on the science equipment used. Its most important characteristic is the development of knowledge of what the equipment can do rather than of gathering reliable data to solve problems. One, of course, does use a data gathering routine but that must not be a limiting factor.

In most science curriculum projects the need to familiarize teachers is recognized both at pre-service and in-service levels; as a result, in a number of Commonwealth countries special "briefing" courses are organized.

What is not fully realized, however, is that familiarization is only one of several stages. Very often, also, it is not realized that science teacher supervisory staff and science education officers themselves need training in the use of low-cost science teaching equipment.

The Practice Stage

"When we use a hammer to drive in a nail, we attend to both nail and hammer, but in a different way... When we bring down the hammer we do not feel that its handle has struck our palm, but that its head has struck the nail. Yet in a sense we are certainly alert to the feelings in our palm and the fingers that hold the hammer." The words describe the essence of skillfulness that comes from practice. It is not enough to know how to use low-cost science teaching equipment, one should use it as second nature. And it is only through practice that one achieves that level of performance.

In the early stages of using a tool there is a tendency to pay primary attention to the tool itself rather than to what it does. Practice enables the learner to go beyond that level and begin to see the meaning of the piece of equipment. I am not referring just to an intellectual understanding of meaning, I include also the physical sense of understanding - of feeling the weight of a piece of equipment without touching it and of knowing the extent of physical effort required to use it properly. And I am referring to all pieces of equipment, from the smallest to the largest. When a learner has acquired that sense, the equipment has ceased to be the object of attention, it has become an instrument of attention. The object of attention can now become purely the data furnished through the use of the instrument.

We are thus aware of both the piece of equipment and the objective of our using it. But the starkness of the equipment seems to have receded in our mind; we are aware only of what it means and that is what guides us in using it effectively. On the other hand, the objective of our activity and the data we obtain seem to be in sharper focus; the equipment has become "second nature" to us. Whenever the equipment is our major focus, the objective and data recede in our mind and vice versa. If one cannot resolve or organize this shift of focus, confusion is likely to result, and better science students will often voice that confusion in an attempt to clear it.

Practice should be given in the context of problems or "investigations" involving use of selected equipment. It should continue until the equipment is viewed as an instrument. The practice stage also incorporates evaluation, preferably self-evaluation, and may lead to the modification of techniques of handling equipment on the basis of that evaluation. This is the stage when a teacher trainee can try to use pieces of equipment as suitable instruments in situations beyond the original specified purposes (.e.g. a ruler serving as a balance board instead of being just a measure of length).

The Stage of Transfer

It is not enough for teachers to possess skills, they must also make it possible for others to acquire them. That is the fourth stage in the training of teachers in the use of low-cost science equipment. The teacher guides young students as they learn to use the equipment during science lessons.

The decisive factor in this stage is the integration of skill performance with an appropriate science education approach.

From the above description, it may seem that each stage is normally supposed to occur only after mastery of the preceding one. This is not the case. The distinctions are intended only to sensitize the trainer to learner needs. It is his duty to judge the stage at which each learner is performing and, therefore, to determine what kind of guidance he might need.

Concluding Remarks

I have attempted to show that the problem of training teachers in the effective use of low-cost science teaching equipment should not be separated from the general approach to teacher training. No distinction has been made between the pre-service and in-service phases because the process is the same in both cases.

Also, the training described would form an integral part of any science curriculum development effort. The reason is that science teaching equipment exists not for its own sake, but as a means for the promotion of understanding. It should, therefore, be introduced in the context of the whole science education approach.

Four stages in the evaluation of progress of a learner teacher towards attainment of effective use of equipment have been identified. The stages should not be pre-set in the training programme, they merely indicate the kind of assistance the learner requires. It would have been probably useful to describe the performance characteristics at each stage more precisely, but that is not possible in the absence of more data and more organized observation of learners.

In conclusion, it should be stated that this paper should not be viewed as giving answers, but as providing only a framework for a discussion. Undoubtedly, the participants from projects in the region will be able to provide more concrete suggestions on the basis of their experience.

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COMMONWEALTH CO-OPERATION IN EDUCATION WITH SPECIAL REFERENCE
TO SCIENCE EDUCATION

Presented by the Education Division of the
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This paper gives an overview of the educational programme of the Education Division of the Commonwealth Secretariat, and indicates areas in which co-operation can be further promoted, especially in science education in member countries of the South Pacific region. These areas can be described as: the collection and dissemination of information; the organization of conferences/seminars; the organization and support of training courses; the promotion and support of professional Commonwealth associations; and collaboration with other inter-regional or international organizations. Apart from the regular Secretariat budget, most of these activities are financed through the Commonwealth Fund for Technical Co-operation (CFTC).

Information

The Commonwealth Secretariat acts as a clearing-house for information about educational developments world-wide, particularly in the Commonwealth.

The collection of information is done in various ways, for example, through visits by staff to the various countries or by visitors to the Commonwealth Secretariat, through correspondence, journals and periodicals which the Education Division receives, and through participation by staff in Commonwealth and non-Commonwealth regional and international meetings. When necessary, the Secretariat commissions specialists to undertake studies/surveys of various subjects. It was, for instance, one such commissioned study that resulted in the publication The Production of School Science Equipment.

The dissemination of information is effected through a number of publications. Reports of Commonwealth meetings as well as results of various commissioned studies and surveys are published from time to time. Also published are the Education in the Commonwealth series dealing with various aspects of education, and a number of special publications such as Educating and Training Technicians and Mathematics Teaching in Schools.

Meetings

Commonwealth Secretariat meetings dealing with education vary from large triennial ministerial conferences and pan-Commonwealth specialist conferences to smaller meetings like workshops, seminars and symposia on various aspects of education. The Secretariat is paying increasing attention to the seminar-workshop type of meeting which, in addition to discussing problems in general terms, provides some measure of training for participants. The present workshop at which practical laboratory work features quite prominently is a case in point.

Training

The Commonwealth Secretariat provides and supports training in various ways, some of which are:

- (a) Bursaries: The Secretariat encourages Commonwealth countries to send personnel to train at courses which are already in existence. Emphasis in training has been mainly on the training of middle-level personnel and awards have been made for a wide variety of courses in technical and professional institutions, including such well-known centres as the Regional Educational Centre for Science and Mathematics (RECSAM) and the Colombo Plan Staff College for Technician Education.
- (b) Provision of Consultants: The Secretariat often procures consultants to assist in national, regional and pan-Commonwealth training programmes. For instance, in 1978 a team of consultants assisted by local counterparts carried out a study in the Bahamas which, it is hoped, will lead to training of science and mathematics educators for effective teaching and learning of these subjects. Also, whenever possible, Secretariat staff are made available from time to time to provide advice to governments, UNESCO and other regional and international organizations.
- (c) Regional Training Courses: Where regional training courses already exist, as for example in RECSAM, the Secretariat is prepared to consider requests to support personnel sent there for training.

Since 1977, the Commonwealth Secretariat has launched its own programme of regional courses. The first course, held in Nairobi, Kenya, from January to April 1977, provided training in educational administration and supervision for school administrators and supervisors drawn from Commonwealth Africa. A second 10-week course dealing with the same subject was held in Fiji for similar personnel from Commonwealth Pacific countries from May to July 1978, and the third in the series is planned for the Caribbean region in May this year.

Another course which merits mention here is a Commonwealth Caribbean regional course in Book Development, held in Guyana from July to September 1977 for personnel from Ministries of Education, other Ministries, and other institutions.

- (d) Educational Visits: The Secretariat has in the past provided a number of grants to enable personnel from the developing countries to travel to other developing countries so as to examine special areas of interest in education. Though these visits have proved useful, it is now thought that training attachments would be even more desirable.

Teaching about the Commonwealth

It is recognized that much ignorance exists in Commonwealth countries about what the Commonwealth is, what it does, and what it has to offer to member countries. Commonwealth Heads of Government therefore gave strong support in 1977 for programmes to improve the knowledge and understanding necessary for effective co-operation between member countries. In August 1978, the Secretariat provided support to an African regional seminar on Teaching about the Commonwealth, which was organized in Nairobi by the African Social Studies Programme. The Secretariat next plans to sponsor a similar seminar in the Caribbean.

Commonwealth Association

The Commonwealth Secretariat gives support to a number of non-governmental organizations. One such body, the Commonwealth Association of Science and Mathematics Educators (CASME), is serviced by the Education Division of the Secretariat. It is an Association aimed at promoting the social significance of science and mathematics education. Founded in 1974, it has already organized two regional seminars; the first held in Accra in 1975 dealt with "Languages and the Teaching of Science and Mathematics with Special Reference to Africa"; the second concentrated on "Relevance in Science and Mathematics Education" and took place in New Delhi in 1978. A third seminar on "Training Science and Mathematics Educators with Particular Reference to the Social Context" is planned for the Pacific region in Darwin, Australia, in March 1980. CASME also publishes a quarterly journal, The Science Teacher which is distributed free to members. The Association also organizes an awards competition for science and mathematics educators annually.

The Commonwealth Association of Polytechnics in Africa

As a first step towards the ultimate establishment of a pan-Commonwealth Association of Polytechnics, the Secretariat, through the Education Division, initiated and supported the launching, in December 1978, of a Commonwealth Association of Polytechnics in Africa. This resulted from a recommendation of the Commonwealth Ministers of Education Conference, last held in Accra, Ghana in March 1977. An Executive Committee headed by a President, and three Vice-Presidents came into being with temporary headquarters in the Polytechnic of Mombasa, Kenya. The main objectives of the Association are to foster the exchange of staff and students, and to assist the development of curricula, research and teaching experience in these young institutions in Africa.

It is planned to launch a similar Association in the Asia-Pacific as well as the Caribbean regions in the next few years. In this way, co-operation in the fields of staff training, student curricula, and the production of technical and vocational equipment will be increasingly encouraged. Clearly, the issues of science teaching equipment and the training of technicians for maintenance and production are closely related to the existence of such an Association, and participants will no doubt wish to follow developments in this field most attentively.

Co-operation in Science Education in Commonwealth Pacific Countries

Apart from the common features in the structure of education in South Pacific countries, it is interesting to note from the country reports presented at the workshop that the problems of teaching science in these countries are strikingly similar - over-dependence on expatriate staff and on importation of equipment from overseas with all the attendant difficulties and frustrations. It is therefore not surprising that the workshop discussed the possibility of establishing a regional equipment production centre.

Inter-Regional Co-operation

The similarity of problems in science education throughout the Commonwealth confirms the value of co-operation between science educators in this region, in Africa, in the Caribbean and in Asia. The need to reduce wasteful experimentation where relevant experience and systems are already available in member countries has long been recognized. So has the need to facilitate inter-

regional travel, wherever possible. The presence of representatives from Guyana and Malaysia at this workshop illustrates this point. What needs to be emphasized is that all countries should endeavour to take advantage of pan-Commonwealth conferences and seminars to make post-conference study visits and to look beyond regional frontiers for opportunities of Commonwealth co-operation in science education. However, it is also crucial to the success of such co-operation that communication channels within Education Ministries/Departments should be strengthened and generally improved, and that mechanisms for regional and inter-regional collection, dissemination and exchange of information and experience should be increased and, where necessary, streamlined. Information on educational experiments, innovation, problems, and how such problems have been solved, should be forwarded to the Secretariat's Education Division which is currently reviewing its educational newsletter with a view to improving its clearing-house function for member states.

It is in this way that the Commonwealth Secretariat as the central agency can be assisted by member states to improve its service to individual countries and to the Commonwealth as a whole. For we believe that such a two-way flow of educational information is critical to the continuing value of Commonwealth co-operation in education generally and in Science and Mathematics education in particular.

ADDRESSES

ADDRESS BY MR. M. TIGILAI

ACTING VICE-CHANCELLOR, UNIVERSITY OF TECHNOLOGY, LAE

Firstly on behalf of the University, I would like to welcome you all into the Campus. I hope that you will have time to look around the Campus and also in the Departments to see what facilities we have here.

This University started off as an Institute of Higher Technical Education in 1967 and then in 1973 its status changed into a University of Technology. At that time it had an intake of about 400 students. Since then the total intake has increased to 1150 at which level we have held the number for the last year and this year and perhaps in the next few years yet. It is a pity really considering there is so much demand for our graduates.

Ten per cent (10%) of that total intake comprises of students from countries in the South Pacific region plus others. This year we have eighty four (84) students from Fiji, Tonga, Western Samoa, New Hebrides, Gilbert Ellis Islands and the Solomons.

We have made our equipment available because of the importance we place on this Workshop; we realize how important it is to know how to maintain science equipment and we are looking forward to gain something from this Workshop. Like the countries represented here, Papua New Guinea is a developing country and as such all our science equipment is imported. As we are all aware when we import equipment we only import the technology but not the skills in maintaining them. The Workshop is therefore of importance to us all to learn something by which we all hope to provide for this need in our various countries.

Before I finish I wish to thank the Commonwealth Secretariat for making this Workshop possible but also ask participants that we should make good use of this occasion to gain for ourselves and our countries the knowledge of how to maintain our usually expensive science equipment. I would like to wish you well in your deliberations.

Please do not forget that if you have an opportunity, feel free to visit the University Departments and see our facilities. Once again I welcome you all to our Campus and hope you enjoy your stay here for the next two weeks.

ADDRESS BY H.E. MR. DONALD MIDDLETON
BRITISH HIGH COMMISSIONER TO PAPUA NEW GUINEA

The phrase 'the living Commonwealth in action' is not a new one, but it can certainly be used with accuracy today to describe this meeting. We are here, representing as the delegates do, many different and widely scattered nations, to share knowledge and experiences, and in a sharing, co-operative venture to learn, and to produce new ideas. This type of non-competitive, non-point-scoring consultation, be it in the field of education, law, technology or the arts, is taking place all over the Commonwealth, almost every week of the year, and is proof of the purposeful, practical value of this special link between English-speaking peoples with common aims.

I should like to observe that although the subject of this particular meeting is scientific, and although it is being held in a university uniquely devoted to scientific studies, it is good to see that not all of us here are scientists! It is so obviously right to emphasize the need for school boys and school girls, and students of tertiary institutions, to have a basic knowledge of our present scientific world, that it is difficult to understand why we have been slow to meet the requirement. Why have we allowed science and technology to become a province of the favoured few - teaching these specialized skills as though they were endowed with a mysticism beyond the comprehension of the ordinary person? One reason has been the belief that scientific knowledge could be acquired only with the help of complicated, delicate and above all expensive teaching aids. Thus, for generations in many parts of the world (including my own country) only a minority of pupils have been able to benefit from science teaching - in the main those attending well-endowed, large schools or colleges where the cost of laboratory equipment could be afforded.

The very fact of this workshop shows the recognition of the problem and a determination to solve it. The international composition of the gathering will ensure that suggested solutions are critically examined from many viewpoints. The attendance of teachers - those actually facing the problem - will prevent the 'experts' from having it all their own way! Above all, the cumulative experience of the Commonwealth Secretariat will be available to point the way.

Words of thanks will be properly spoken at the end rather than at the beginning of a meeting such as this. But it would be unwise from the start not to appreciate our indebtedness. First, to the Commonwealth Secretariat for focussing our attention on these matters and being ready to organize the workshop. Secondly, to the Papua New Guinea Department of Education for sponsoring a conference which is intended to give help to many peoples throughout the Pacific. Thirdly, to the Council of the University for providing so suitable a venue. Fourthly, to the thinkers who will present their ideas and lead the discussions.

A fundamental precept, which is wisely emphasized by the Government of Papua New Guinea, is the value of self-reliance. Without pre-judging the outcome of this workshop, I feel able to suggest that improvisation and simplicity in the use of materials for science teaching, is a theme which is closely related to self-reliance. It seems therefore especially appropriate that this conference should be taking place in Papua New Guinea, a delightful country in which I am privileged to be living and working.

Mr. Vice-Chancellor, distinguished representatives and delegates, I have much pleasure in formally declaring the workshop open.

ADDRESS BY MR. REX. E.O. AKPOFURE
DIRECTOR, EDUCATION DIVISION, COMMONWEALTH SECRETARIAT

Mr. Vice-Chancellor, your Excellency, distinguished guests, ladies and gentlemen. It is my privilege today, in responding to the Opening Address, to bring you on behalf of the Commonwealth Secretary-General H.E. Mr. Shridath Ramphal greetings and good wishes from the Commonwealth Secretariat. This workshop and our presence here so far from London are a concrete expression of the practical concern of our Commonwealth for the development of our member states - spread, as we are, right across the globe. It represents our belief in the value of interaction and mutual co-operation by countries which include the wealthiest and the poorest, the highest and the lowest populations ranging from 600 million to only a few thousand and from the most developed and advanced to the merely developing. In that sense therefore, the Commonwealth today is as relevant to our search for a better life as any of man's global associations. For that reason also our modest contribution to that global effort wherever it is made must merit attention. That on this occasion such an effort is taking place here in Papua New Guinea is no accident; rather it is the result of a belief that the search for solutions to problems can best be pursued in the context where they exist. At the same time it is comforting to know that these problems are shared to a greater or lesser degree in common, throughout our member states.

This workshop is the third in a series of such efforts designed to get to grips, at regional level, with the thorny question of producing low-cost science equipment in our countries, given the scanty resources of men and money and the clamouring demands made on those resources by all sectors of the economy. Yet it is more than that: it is to deal with the issue at once of effective science education and development education. The Commonwealth Secretariat is not the only, or even the most important organizer of workshops and seminars in these fields. Its distinctive characteristic lies in its motivation: it responds to needs clearly identified (whether in Education or Science or Finance or Economic Affairs) by our member states themselves as priorities for action through co-operation.

In this workshop, for the next twelve days, we shall be concentrating, on 'Training in the Production and Use of Science Teaching Equipment' in our schools and colleges. In recognition of how wide-spread is the problem throughout the developed and developing Commonwealth, we have at this workshop representatives of this Region - including Australia and New Zealand - as well as one inter-regional representative each from the Caribbean, Asia and Africa. In all of the countries involved the critical importance of low-cost equipment to the teaching of effective science has long pre-occupied the planning and provision of education and its curriculum.

At the same time, there is an emerging recognition of an important principle. It is the need to develop to a greater degree than ever before a measure of self-reliance in dealing with problems. The first is to re-emphasize in practice that science lives and abounds all around us and needs to be imported from no other country: that the air we breathe and heat and light, the rivers and forests, rocks and soils, the flora and fauna all these may be studied without foreign exchange considerations provided science is taught by means of nature all around us. In this sense, education and development are inevitably bound together; and if we learn and teach science through the environment the development process cannot be too far away! The present series of workshops of which this is the last is organized as an attempt to accelerate that process of natural growth and development, through self-reliance.

Mr. Chairman, the Commonwealth, through its Secretariat and in this case through the CFTC, encourages and fosters co-operation in many fields and especially in Education, Health, Law and Legal Drafting, Government and Administration, Economic and Industrial matters. The extent of our effectiveness is determined largely by the support given by each member state whether in the form of financial contribution or through the hosting of regional meetings, seminars and workshops. Yet, such meetings and workshops would be of little value if their recommendations and proposals ended up on the dusty shelves of pre-occupied departments and ministries or in musty archives or libraries of our countries. It is the existence of the will to implement proposals which have relevance in our countries that makes such meetings worthwhile. That will, is an important, indeed critical form of support to Commonwealth action.

It is for such support therefore, that I wish today to express the appreciation of the Commonwealth Secretariat. We would not be here today, but for such support. We would be unable to share experience and the possibility of renewed insight into familiar problems without such support. Indeed, our experts and specialists would have little hope of contributing outside their own countries but for such support, from our member Governments. This, Mr. Chairman, is the essence of the modern Commonwealth Association both on the regional and the inter-regional levels.

Our thanks must go, first, to the Government and people of Papua New Guinea for their generosity in hosting this workshop for the Pacific Region. Already, we recognize how critical to its success will be the facilities and resources it has put at our disposal. To you, Mr. Vice-Chancellor, we bring our appreciation for opening your gates to us and placing so freely at our disposal the specific technical and professional requirements we need from your University. I assure you that we will leave you no room to doubt that they will be fully utilized.

To you, your Excellency, for undertaking to perform on behalf of the Government of this country, the official opening of this workshop, we also express our appreciation. You have demonstrated once more your country's abiding support for the Commonwealth and its objectives - a support on which we have learnt to depend.

I cannot neglect Mr. Chairman, the opportunity to express our thanks to our observers from other agencies i.e. the UNDP, Unesco and the British Council who have found time to be associated with us in this undertaking. The Commonwealth Secretariat, in its relatively short existence, has always attached considerable importance to inter agency co-operation and we value today your affirmation of your organizations reciprocity in this regard.

Finally, I must also thank our consultants from the United Kingdom and Nigeria for coming all this distance, particularly at rather short notice, to assist us at this workshop. I have already assured them that in the next few days we intend to 'milk' them fully. To all of you who have come to this ceremony today and all who in your various ways have already assured us of your support and services, I must end with thanks for your assistance and co-operation. With such auspicious and encouraging beginnings, we are confident that the problems with which we are trying to grapple cannot but diminish in their terror.

ORGANIZATION OF THE SEMINAR/WORKSHOP

AGENDA

Theme

Low-Cost Science Teaching Equipment

Objectives

The workshop was held to:

- (a) consider methods by which school science equipment is most effectively developed and the implication for teacher education, of effective teacher participation in innovative strategies of teaching through the use of low-cost science equipment;
- (b) provide workshop experience in designing, developing and evaluating locally-constructed low-cost science teaching equipment;
- (c) examine ways of improving Commonwealth co-operation in the development and production of school science equipment.

Agenda Item I: Training for Production of Low-Cost

Science Teaching Equipment

- (a) Existing sources of equipment and alternatives
- (b) National and regional production units
- (c) The role of the teacher in production
- (d) Training of personnel for production
- (e) The role of the educational administrator
- (f) Relationship between local production units and commercial supplies

Agenda Item II: Training for Use of Low-Cost

Science Teaching Equipment

- (a) Why practical work in science?

- (b) Equipment as a tool in understanding science
- (c) Problems associated with the use of equipment
- (d) Stages in the training of teachers in handling and using of equipment
- (e) Pre-service teacher training
- (f) In-Service teacher training
- (g) The role of science education organizations

Agenda Item III: Commonwealth Co-operation in Education with Special reference to Science Education

- (a) Information
- (b) Meetings
- (c) Training
- (d) Teaching about the Commonwealth
- (e) Bilateral co-operation
- (f) Pan-Commonwealth and regional co-operation in science education

Agenda Item IV: Practical Laboratory Sessions

- (a) Examining low-cost materials developed in some member countries
- (b) Recognizing and assessing equipment from manufacturers catalogues
- (c) Basic workshop techniques and economics
- (d) Safety in science laboratories
- (e) Design, developing and producing prototype equipment and related learning materials for science teaching
- (f) Evaluating equipment and related learning materials for science teaching

TIMETABLE

Monday 19 March

11.00 - 12.30 Registration

Tuesday 20 March

11.00 - 12.30 Opening

2.00 - 3.30 Country Papers (Plenary)

4.00 - 5.30 Country Papers (Plenary)

6.30 - 8.00 Reception: Government of Papua New Guinea

Wednesday 21 March

9.00 - 10.30 Country Papers (Plenary)

11.00 - 12.30 Training for Production (Plenary)

2.00 - 3.30 Laboratory: Session 1

4.00 - 5.30 Training for Use (Plenary)

Thursday 22 March

9.00 - 12.30 Educational Visits

2.00 - 3.30 Training for Production (Groups)

4.00 - 5.30 Training for Production (Groups)

6.00 - 9.00 Reception: Vice-Chancellor, Papua New Guinea
University of Technology

Friday 23 March

8.30 - 10.30 Training for Production (Groups)

11.00 - 12.30 Training for Use (Groups)

2.00 - 3.30 Training for Use (Groups)

4.00 - 5.30 Training for Use (Groups)

Saturday 24 March

11.00 - 12.30 Training for Production: Report by Groups

4.00 - Excursion - Wau Ecology Institute, Wau

Sunday 25 March

- 4.30 Excursion - Wau Ecology Institute

Monday 26 March

8.30 - 10.30 Training for Use - Group Reports

11.00 - 12.30 Laboratory: Session II

2.00 - 3.30 Laboratory: Session III

4.00 - 5.30 Laboratory: Session IV

Tuesday 27 March

9.00 - 10.30 Free

11.00 - 12.30 Laboratory: Session V

2.00 - 3.30 Laboratory: Session VI

4.00 - 5.30 Commonwealth Co-operation in Education (Plenary)

Wednesday 28 March

9.00 - 10.30 Laboratory: Session VII

11.00 - 12.30 Laboratory: Session VIII

2.00 - 3.30 Laboratory: Session IV

4.00 - 5.30 Drafting of Recommendations (Plenary)

Thursday 29 March

9.00 - 10.30 Laboratory: Session X

11.00 - 12.30 Laboratory: Session XI

2.00 - 3.30 Laboratory: Session XII

4.00 - 5.30 Laboratory: Session XIII

6.30 - 8.00 Reception: Commonwealth Secretariat

Friday 30 March

8.00 - 10.00 Approving Report (Plenary)

WORKSHOP GROUPS

Discussions on Agenda Item 1

Group A

Mr. I. Rainibogi (Fiji) (Chairman)
Mr. Don Zoellner (Australia)
Miss P. Kila (PNG)
Mr. Gogobe Mairi (PNG)
Mr. S. Tapualiki (Solomon Islands)
Mr. T.K. Holani (Tonga)
Mr. Alec Farley (Guyana)
Mr. A.F. Edwards (British Council)
Mr. Carrol Poyep (PNG)
Mr. Michael Davis (UNDP/UNESCO)
Mr. Allen R. Inverssin (ATDU)
Dr. S.T. Bajah (Consultant)
Dr. P. Logan/Mr. I. Brazier
(Rapporteur)

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Mr. Donald M. Ferguson (New Zealand)
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Mr. M. Tapo (PNG)
Mr. R. Songan (PNG)
Mr. G. Blackburne (Solomon Islands)
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Mr. B. Wilson (PNG)
Mr. Brian Miller (PNG)
Mr. Brian Deutrom (PNG)
Mr. Norman Lowe (Consultant)
Mrs. Margaret Van Der Werff
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Discussions on Agenda Item 2

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Mr. Alec Farley (Guyana)
Mr. A.F. Edwards (British Council)
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Mr. Michael Davis (UNDP/UNESCO)
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APPENDICES

QUESTIONNAIRE FOR PROBE OF APPARATUS MARKET

Part 1

1. Name of school:
2. Name of person to whom correspondence should be addressed:
3. Telephone number:
4. Type of school:
5. Number of pupils in school:
6. Level to which pupils are taught:
7. Number of parallel streams:
8. Are the following subjects taught separately? physics; chemistry; biology:
9. Is general science taught as well as, or instead of, above separate subjects?
10. Average number of pupils per class:

Part 2

11. How much money, if any, is spent at present on apparatus annually for
(a) physical sciences? (separate into physics and chemistry, if possible)
(b) biological sciences? (c) general science?
12. Are you interested in the samples of apparatus shown?
13. At the prices asked, how much would you buy?
14. How much would you spend annually if told/shown what was available?
15. Is there any particular time of year when it is easier to buy apparatus because of availability of funds?
16. If there were an apparatus fair at some accessible centre once a year, would you (a) find it useful? (b) attend?
17. Could you, under any condition, pay cash on delivery? If not, what period would be needed for payment?
18. Would you welcome, and use, a periodical pamphlet saying what apparatus is available and outlining its uses, and giving prices and availabilities?
19. For expensive apparatus which is beyond your financial reach, would you welcome the establishment of a pool of apparatus at some local centre from which you could borrow?
20. For the use of the pool outlined in 19, would you be willing to pay a small annual charge to cover the cost of maintenance?

BASIC EQUIPMENT FOR A LOW-COST
SCIENCE EQUIPMENT PRODUCTION CENTRE

For design and development activities combined with an average production worth £100,000 (on no profit, no loss basis), a modest requirement of equipment is given below for a workshop having nearly 2,000 sq. metres of covered area and employing nearly 100 persons. The list may prove uneconomical for small countries. In such cases neighbouring countries may decide to establish a common regional centre to cater for their needs.

A. Design Section

1. Drafting machine, drawing board, instrument box, set squares etc.
2. Ammonia printing equipment.
3. Electronic stencil cutter.
4. Duplicating machine.
5. Screen printing equipment.

B. Development Section

1. Tool room lathe - Height of centre - 150 mm
distance between centres - 500 mm
2. Precision lathe - Height of centre - 100 mm
distance between centres - 300 mm
3. Screw cutting lathe - Height of centre - 200 mm
distance between centres - 1 metre
4. Drilling machine - Capacity - 18 mm
Height of work - 200 mm
5. Padestal tool grinder - Wheel dia - 400 mm
6. All types of handtools for fitting jobs

C. Machine Shop

1. Screw cutting lathe - Height of centre - 200 mm
distance between centres - 1000 mm
2. Screw cutting lathe - Height of centre - 200 mm
distance between centres - 1 metre
3. Precision lathe - Height of centre - 200 mm
distance between centres - 1.5 metre
4. Screw cutting lathe - Height of centre - 175 mm
distance between centres - 1.2 metre
5. Shaping machine - Stroke - 600 mm
6. Padestal tool grinder - Wheel dia - 400 mm - 3 Nos.
7. Power hacksaw - Max. dia of work - 150 mm
8. Universal milling machine - Vertical travel - 300 mm
Horizontal travel - 320 mm
Cross travel - 200 mm
9. Vertical milling machine - Swivel head, travel of head - 200 mm
Vertical travel of bed - 300 mm
10. Horizontal milling machine - Vertical travel - 800 mm
Horizontal travel - 800 mm
Cross travel - 500 mm

- | | | |
|-----|---|---|
| 11. | Universal tool & cutter grinder | - Longitudinal traverse - 400 mm
Cross traverse - 150 mm
Vertical movement of wheel head - 100 mm |
| 12. | Cylindrical grinder | - Max. work diameter - 150 mm |
| 13. | Surface grinder | - Table travel - 710 mm
Vertical travel - 300 mm
Cross travel - 235 mm |
| 14. | Engraving machine | - Horizontal travel - 200 mm
Vertical travel - 300 mm
Cross travel - 200 mm |
| 15. | Turret lathe | - Bar capacity in collet - 18 mm |
| 16. | Semi-automatic capstan lathe | - Bar capacity in collet - 18 mm
Bar capacity in chuck - 50 mm |
| 17. | Pillar drilling machine | - Capacity - 25 mm |
| 18. | Bench drilling machine | - Capacity - 12 mm |
| 19. | Spring winder | |
| D. | <u>Die Stamping Section</u> | |
| 1. | Punch press | - Capacity - 40 ton |
| 2. | Hydraulic press | - Pressure - 400 kg./cm ² |
| 3. | Lathe (gap bed) | - Height of centre - 200 mm
distance between centres - 1 metre |
| 4. | Fly press, hand-operated | - No.4 and No. 6 |
| E. | <u>Sheet Metal & Fitting Section</u> | |
| 1. | Power-operated sheet cutting machine (guillotine shear) | - Length of cut - 2 metres
Max. thickness of sheet - 3 mm |
| 2. | Power-operated sheet bending machine | - Length of bed - 2 metres
Max. thickness of sheet - 3 mm |
| 3. | Hand-operated shear | - Max. thickness of sheet - 16 SWG |
| 4. | Drilling machine | - Capacity - 12 mm |
| 5. | All sheet-metal and fitting hand-tools | |
| F. | <u>Carpentry Section</u> | |
| 1. | Wood turning lathe | - Height of centre - 100 mm
distance between centres - 1.2 metre |
| 2. | Thickness planer | - Max. thickness of work - 150 mm |
| 3. | Foot-operated fretsaw | |
| 4. | Band saw | |
| 5. | Circular saw | - Diameter - 400 mm |
| 6. | Disc and belt sander | - 300 mm disc |
| 7. | All carpentry hand-tools | |
| G. | <u>Plastic Moulding Section</u> | |
| 1. | Plastic injection moulding machine (manual) | - 200 gms. capacity |
| 2. | Plastic injection moulding machine (manual) | - 60 gms. capacity |
| 3. | Plastic injection moulding machine (semi-automatic) | - 100 gms. capacity |

4. Plastic injection moulding machine (manual) - 30 gms. capacity
5. Blowing-moulding machine (manual) - 100 gms. capacity
6. Blowing-moulding machine (manual) - 30 gms. capacity
7. Plastic scrap cutting machine -
8. Vacuum forming machine - 450 x 450 x 200 mm capacity
9. Plastic coating equipment
- H. Optics Section
1. Glass blowing equipment - Set of glass blower tools - 2 sets
Blast burner - 2 Nos.
Small air blower with air flow and pressure valve - 1 No.
2. Lens grinding machine
3. Polishing machine
1. Electro-plating Section
1. Rectifier/motor generator
2. Tanks, salt accessories
3. Polishing machine
- J. Welding Section
1. Gas welding equipment
2. Arc welding equipment (transformer, electrodes etc.)
3. Spot welding machine - Max. sheet thickness - 18 SWG
- K. Foundry
1. Blower and pit furnace for floor moulding
2. Crucibles and all foundry tools
3. Die casting machine (medium)
- L. Painting Section
1. Spray gun
2. Air compressor
- M. Electrical Section
1. Coil winding machine
2. Multi-meter and other metres
3. All hand tools for electrician

- N. General
- 1. Measuring tools
- 2. Inspection tools and gauges
- 3. Cutting tools
- 4. Portable drilling machine with accessories for converting it into other powered tools
- 5. Conveyor belt for inspection and assembly purposes
- 6. Sundries

EVALUATION OF WORKSHOP*

BACKGROUND INFORMATION

1. Name of country
2. (a) Position
- (b) Designation
- (c) Place of Work
3. Academic Qualification: Graduate
 (Bachelors or above) Diploma
-
- Others
4. Working Experience: 1-5 years 6-10 years
- 11-15 years over 15 years
5. Attendance at Low-Cost Science Teaching Equipment Seminars/Workshops

Frequency	National	International
Once
Two Times
Three Times
More than Three Times

6. How did you receive information about this Workshop?

Contacted by the Commonwealth Secretariat	.....
Contacted by National Government	.....
Contacted by National Ministry of Education	.....
Contacted by Academic Institution	.....
Contacted by National Science Teachers' Association	.....

* Please tick wherever applicable

7. Who is responsible for paying your bills for this Workshop?

	Commonwealth Secretariat	National Government	Self Supported
(a) Round-trip Fare
(b) Hotel Accommodation
(c) Feeding

8. How did you travel to this Workshop?

By Air By Road Not relevant

SPECIFIC ASPECTS OF WORKSHOP

How would you rate the following aspects of the Workshop?

	<u>Good</u>	<u>Fair</u>	<u>Poor</u>
Arrangement for obtaining flight ticket
Arrangement for meeting you on arrival at Lae
Hotel accommodation
Arrangement for visits to schools
Arrangement for excursions
Daily transportation

Laboratory Sessions

Organization:	Satisfactory	.....	Fair	.....	Unsatisfactory	.....
Experience gained:	Useful	.....	Fair	.....	Not Useful	.....
Materials provided:	Adequate	.....	Fair	.....	Inadequate	.....
Tools provided:	Adequate	.....	Fair	.....	Inadequate	.....

How would you assess the Lead Papers?

Lead Paper 1: 'Training for the Production of Low-Cost Teaching Equipment'

Content:	Adequate	.....	Fair	.....	Inadequate	.....
Presentation:	Satisfactory	.....	Fair	.....	Unsatisfactory	.....
Time allocation for presentation:	Adequate	.....	Fair	.....	Inadequate	.....

Time spent on group discussion:	Adequate	.....	Fair	.....	Inadequate	.....
Presentation of group reports:	Satisfactory	.....	Fair	.....	Unsatisfactory	.....
Time spent on plenary discussion:	Adequate	.....	Fair	.....	Inadequate	.....

Lead Paper II: 'Low-Cost Science Teaching Equipment: Training for Use'

Content:	Adequate	.....	Fair	.....	Inadequate	.....
Presentation:	Satisfactory	.....	Fair	.....	Unsatisfactory	.....
Time allocation for presentation:	Adequate	.....	Fair	.....	Inadequate	.....
Time spent on group discussion:	Adequate	.....	Fair	.....	Inadequate	.....
Presentation of group reports:	Satisfactory	.....	Fair	.....	Unsatisfactory	.....
Time spent on plenary discussion:	Adequate	.....	Fair	.....	Inadequate	.....

Lead Paper III: 'Commonwealth Co-operation in Education with Special Reference to Science Education'

Content:	Relevant	.....	Fair	.....	Not relevant	.....
Presentation:	Satisfactory	.....	Fair	.....	Unsatisfactory	.....
Time allocation for presentation:	Adequate	.....	Fair	.....	Not adequate	.....
Time allocation for discussion:	Adequate	.....	Fair	.....	Not adequate	.....

YOUR PERCEPTION OF LOW-COST SCIENCE EQUIPMENT

	Agree	Not Sure	Disagree
1. Low-cost science equipment will be inadequate for teaching Primary Science in my country
2. Low-cost science equipment will be <u>adequate</u> for teaching <u>High School Science</u> in my country
3. At the present moment, the production of low-cost science equipment will be feasible in my country

	Agree	Not Sure	Disagree
4. Teachers in my country will not be enthusiastic in the use of low-cost science equipment
5. The use of low-cost science equipment will help students become interested in future work in science
6. The use of low-cost science equipment will make science more relevant to the environment of the learner
7. Teachers in my country are not sufficiently trained to use low-cost science equipment
8. In-service workshops should be frequently organized for teachers who use low-cost science equipment
9. Classroom science teachers should be involved in the mass production of low-cost science equipment
10. Results obtained using low-cost science equipment are grossly inaccurate
11. Low-cost science equipment should only be used in Teacher Training Colleges
12. The use of low-cost science equipment is inappropriate in industrially advanced countries
13. The production of low-cost science equipment should not be undertaken at the regional level but at the national level
14. Low-cost science equipment is not suitable for practical examinations
15. Low-cost science equipment leads to a cheap but ineffective way of teaching science

FREE RESPONSE

1. What is it you like best in this workshop?

2. What is it you dislike most in this workshop?

3. What is it you would have liked to see done in this workshop which was not done?

4. What would you suggest for inclusion in a workshop of this nature in future in the Pacific?
5. How useful has this workshop been to you personally?
6. What would you plan to do as a follow-up to this workshop in your country?
 - (a) In your official capacity?
 - (b) In your professional capacity?

WORKSHOP CONSTRUCTION EXERCISES

One of the aims of these sessions was to enable the participants to experience the tasks involved in designing and constructing a piece of apparatus. The participants, working in groups, selected two topics (one primary and the other secondary) from the Papua New Guinea material on display. They decided what apparatus they would need to teach the topic, designed and constructed it, and prepared a teachers' guide about its construction and use. Finally each group presented its apparatus and materials for discussion and evaluation by the participants. A brief summary follows.

Group A constructed two pieces of apparatus. For their primary-level topic, a rotating colour disc was made using a tin can, a piece of rod, cardboard and string. The group reported on the difficulty experienced in getting the correct colours, and in colouring the disc in the required manner to obtain white when the disc was rotated. For their secondary-level topic, the group chose to construct a hydro-electric generator. Difficulties were experienced in obtaining a suitable electric motor to use as a generator, and in constructing the water wheel.

For their primary-level topic, Group B chose to construct apparatus to enable simple electric circuits to be investigated. The bulb holders, switch, and battery holders were made from tin lids, strips of tin cans, bamboo and plywood. The group showed how robust apparatus could be made easily from materials brought to school by pupils. The topic chosen for the secondary level was the 'expansion of liquids'. The apparatus required was constructed from two identical bottles, two empty plastic tubes (taken from ball-point pens), and a paper screen. During discussions two difficulties were considered. One was that of getting identical items so as to make a true comparison and the other was that the concept of unequal expansion of liquids might be hard for an inexperienced teacher to explain.

A piece of apparatus to demonstrate electro-magnetism was constructed by Group C for their primary-level topic. The apparatus involved winding a coil and making a stand to support a suspended rod inside the coil. Discussion took place on the construction techniques and also on the versatility of the apparatus in relation to other topics on electricity. A hydro-electric generator was constructed for the secondary-level topic on energy transfer. The apparatus consisted of a tin can with a water wheel and jet, connected to a bicycle dynamo which, in turn, was connected to a torch bulb. Considerable discussion took place on both of the above items, particularly in relation to the skills needed for the manufacture, and the time involved. It was felt that the services of a production unit would be needed if all schools were to have such items. Another point referred to was that a school would need running water to use such a piece of apparatus. This highlights the problem of developing apparatus to suit the facilities available.

Group D chose to investigate alternative designs for a pin-hole camera for use when teaching 'light' at the primary level. Various designs were made using tin cans, bamboo, cardboard and ruled paper. For the translucent screen, typing paper with some oil on it was found to be effective. An alternative was a plastic lid found on some tin cans. For their secondary-level topic the group constructed two forms of insect cages and a simple

potometer using a syringe, plastic tubing and a broken rule. In addition, a storage box for 12 spirit burners was constructed and presented as an idea whereby teachers could store their apparatus in boxes and easily ensure that all items were returned at the end of a practical session. Discussions revolved around the need to incorporate such activities in teacher training courses as all of the above items were well within the capabilities of any teacher who had had some basic training in construction techniques.

Group E took the field of electricity as its overall topic and constructed apparatus for three levels - primary, lower secondary and upper secondary. For the primary level an electric buzzer was constructed. For the lower secondary level a piece of demonstration apparatus was made for showing the magnetic effect of an electric current. As a third item the group constructed an electric motor using nails, screws, wire and other easily obtainable materials.

Discussions took place on the suitability of the apparatus for demonstration purposes particularly in relation to the size of apparatus for large group viewing.

Before considering the specific activities of each group some general observations are worth mentioning. These are provided to highlight areas which need particular attention when incorporating such activities in teacher education, and to reinforce the need for appropriately trained personnel when considering the design, development and production of school science equipment.

1. It is interesting to note that, for the primary level, all groups selected a physics topic for their activity even though material was also available on chemistry, biology and mathematics. For the secondary-level topics all but one group again chose physics. Whether the selection of physics was due to the pre-conditioning (when considering apparatus construction) is not quite clear. It is a point for consideration when introducing construction activities in teacher education programmes. Free choice of activity may not provide a balanced cross-section particularly for teachers of integrated science.

2. Though each group was expected to produce a design and list the necessary materials before the construction of the prototype commenced, it is probably true to say that many of the 'designs' came after the construction (i.e. development was based on 'trial and error'). This approach is acceptable but it is usually used to perfect a design rather than create a new one. By listing the requirements and working to a sketch, a number of 'false starts' can be avoided, thus saving time and preventing material from being wasted. A point to bear in mind is that enthusiasm can sometimes hinder rather than help. Good initial planning and design avoids unnecessary procurement of items which may not be used. In this particular workshop the technical staff and resource personnel often found themselves stretched to provide items and constructional details as 'good ideas' grew.

3. As can be seen from the presentations of the groups, preparation of the guide for construction and use is a most difficult task. Even when a prototype has been produced, the task of making instructions for other people to follow requires considerable skill. Much discussion took place on this aspect during the plenary sessions.

4. Basic training in simple constructional techniques must be given before a teacher can be expected to develop his own apparatus.

5. Time and physical resources limit what an individual teacher can do. For example, is it possible to obtain 40 tins for one class activity?

6. The size of a piece of apparatus is important if it is to be used for demonstration purposes.
7. When preparing teachers' guides for constructing and using apparatus, step-by-step instructions are needed to avoid any misunderstanding or ambiguity.
8. Diagrams should be clearly drawn, labelled, and related to specific parts of the text, particularly when constructing a number of items which will have to be assembled for one piece of apparatus.
9. A clear indication of sizes should be given for the benefit of the inexperienced teacher.
10. A basic kit of tools should be available in every school to enable teachers to construct items. An example is shown on page . The workshop construction exercises which follow are presented as similarly as possible to those that were submitted; slight alterations in the drawings and text have, however, been made where a little extra clarity was needed.

GROUP A.

Topic: LIGHT

Sub Topic: Making Colours White

Materials Needed

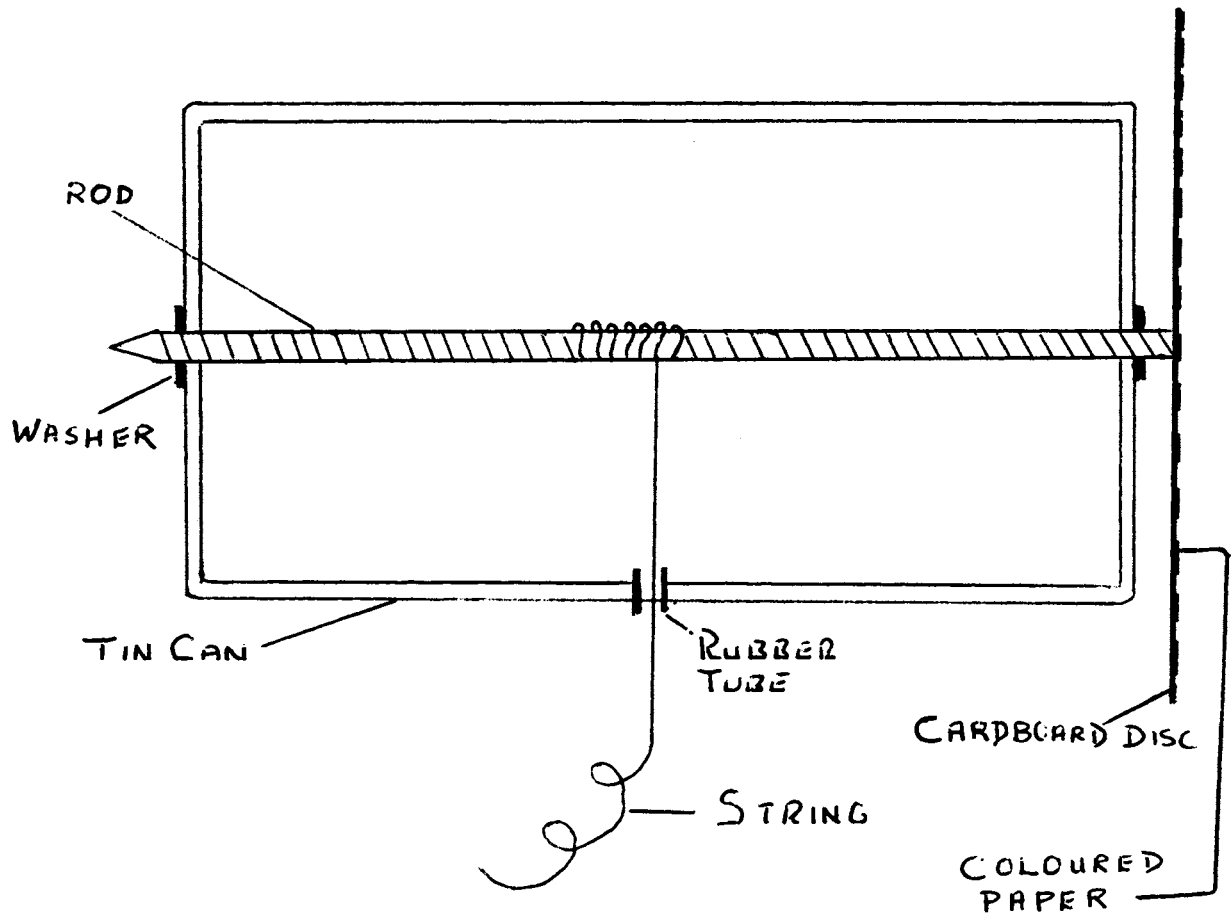
Empty Can (e.g. coffee tin) with a lid.
Strong thin string (about 1 metre in length).
Circular cardboard (e.g. plywood, masonite) about 14 cm. dia.
Wood dowel (circular stick, metal rod, etc.) about 5 to 7 mm dia.
White paper to fit circular disc.
Glue to stick paper onto cardboard.
Small washers or discs to fit rod.

Steps in Construction

1. Make circular holes in the centre of the lid and base of the can. They should be slightly larger than the diameter of the rod.
2. Bore a small hole in the side of the can about half way along.
3. Cut out two circles about 14 cm. in diameter, one from the cardboard and one from the white paper.
4. Divide the circular white paper into seven equal segments and colour each segment in the following order of colours:

Red; Orange; Yellow; Green; Blue; Indigo; Violet.
5. Glue the coloured circle onto the cardboard circle.
6. Make a hole in the centre of the disc so that the rod is a tight fit in the hole. Glue them together. (Araldite).
7. Place a small washer on the rod and fix it a short distance from the disc. Feed the rod through the lid.
8. Firmly attach the string to the centre of the rod and feed the string into the tin and out of the hole in the side. Fit the tin lid with the disc and rod, carefully fitting the rod through the hole in the base of the tin and fit second washer.
9. Wind the string onto the rod by turning the cardboard disc.
10. Tie a knot or loop on the end of the string so that it cannot enter the tin.
11. Give an even pull on the string to rotate the disc. Leave the string to hang loosely so that it is able to rewind onto the rod. Repeat this action for further rotations.

APPARATUS FOR MAKING COLOURS WHITE



GROUP A.

Topic: ELECTRICITY

Sub Topic: Hydro-electric Power.

Note: Hydro-electricity is a source of power in most countries. In some it is the most important single source of electricity. It is therefore desirable for students to understand the basic technology.

Materials for making the prototype

Flat circular tin sheet or a large tin lid.

No. 8 wire or a metal rod about 2mm dia., and about 18cm. long.

Flat metal strip.

Two pulleys.

One motor from a toy or tape recorder.

A piece of timber for the base; about 15cm. x 30cm. x 2cm.

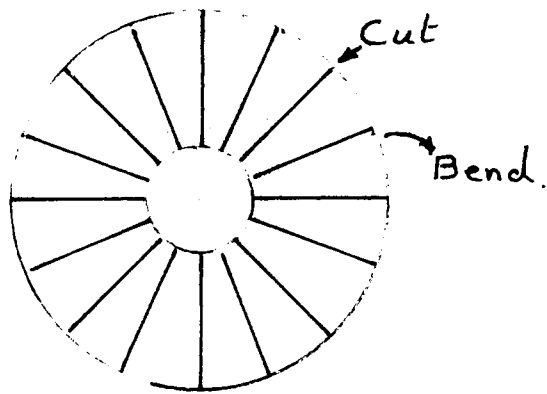
Nails or screws.

Steps in Construction

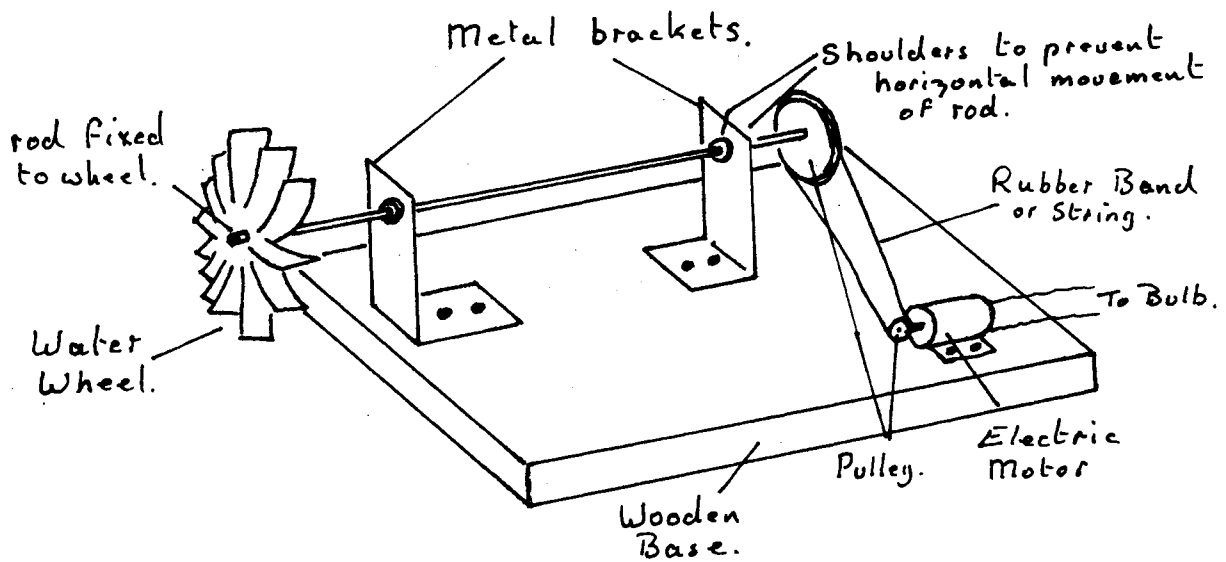
1. The base is prepared using a suitable piece of timber.
2. The water wheel is constructed from the circular piece of tin (tin lid), as follows:
 - i) From the centre of the lid, and using a radius of 2cm. scribe a circle. Then scribe a second circle using a radius of 4cm.
 - ii) Carefully cut out the 4cm. radius disc and, using a drill or nail make a hole in the centre of the same diameter as the rod available.
 - iii) Now divide the circle into 16 to 18 parts of equal size and cut down to the 2cm. scribed circle.
 - iv) Twist the cut so as to form a blade for catching water. All twists need to be in the same direction.
 - v) Fix one end of the rod to the water wheel and solder it in place. (Alternatively use a suitable adhesive such as Araldite).
3. Make two brackets from the flat metal strip exactly the same height. Bore a hole in each at the same height and having a slightly bigger diameter than the metal rod. Fix the brackets to the base.
4. Place a small spacer or shoulder on the metal rod and pass the rod through the hole in the first mounting bracket and then through the second bracket.
5. Place a second spacer (or shoulder) on the rod and fix a pulley onto the rod of about 8cm. diameter using Araldite. (Before fixing the pulley adjust the spacers so that the rod runs freely without sticking.)

6. Mount a toy electric motor (or home-made motor) onto the baseboard and fix a pulley of about 1cm. diameter onto the motor spindle. (The pulley should be in line with the pulley on the metal rod, see the diagram).
7. Make a belt (using string (or some other suitable material such as rubber) and connect the two pulleys together.

As can be seen from the diagram, the water would drive the water wheel which in turn, drives the motor (dynamo). This can then be connected to an electric circuit to light some bulbs.



Construction of the Water Wheel.



Arrangement of Apparatus for Demonstrating Hydro-electric Power.

Group B.

Topic: ELECTRICITY

Sub Topic: Let's find out how to light more than one bulb at the same time.

Materials Needed

Battery holder with terminal wires.
Two bulb holders with wires attached about 20cm. long.
One switch with wires attached about 20cm. long.
Two 1.5 volt dry cells (batteries).
Two 2.5 volt screw-type bulbs.
Two thin lids.
Flat wood about 10cm. long x 10cm. wide x 4cm. thick.
Screws, nails and insulated wire.
Bamboo of an internal diameter to take the batteries.
Thin metal strip (e.g., as found on packing cases).

Construction of the apparatus

A. Sockets (Two required)

See Sketch 1.

1. Cut the wood to make a 10 x 10cm. square piece.
2. Remove the insulation from the end of a 20cm. length of insulated wire.
3. Screw a small screw (preferably brass) into the wood somewhere near the centre. Wrap the bare end of the wire around the screw and tighten down.
4. Using a 6" nail lay it down horizontally and hammer it into the piece of wood, so that it makes a groove from the centre out.
5. Punch a hole in the centre of one of the metal lids with a nail. Enlarge the hole until the bulb can be screwed into the lid.
6. Nail the lid on to the piece of wood using 3 x 3cm. nails, making sure that the hole is directly above the screw. Leave $\frac{1}{2}$ cm. of one nail above the lid.
7. Connect the bare end of another length of insulated wire to the nail and hammer it in.
8. Screw one of the bulbs into the hole by turning it until it touches the screw below.
9. Now make a second similar socket.

B. The Switch (one required)

See sketch 2.

1. Cut a piece of the wood to make a 7cm. square piece (approximately).
2. Cut a piece of the metal strip into a piece of about 6cm. x 1cm. using a pair of tin snips.
3. Make a hole in one end, using a nail and hammer. The hole should be made to the size of an available wood screw.
4. Screw one of the screws into the wood. Before screwing down wind one bare end of another length of the insulated wire around the screw and then screw firmly down.
5. Push the second screw through the hole in the metal strip and screw into the wood. The position should be such that the other end of the metal strip should overlap the screw already in the wood. As for the first screw the second one should have a bare end of insulating wire connected to it. Cut the lengths of wire off at about 2 cm. lengths.

C. Battery Holder (one required)

(See sketches 3 & 4)

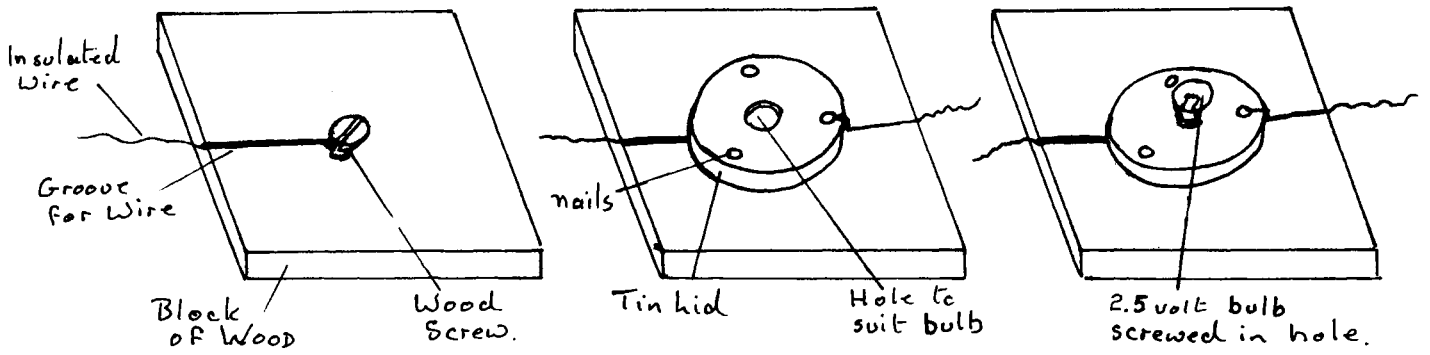
1. Having chosen a suitable piece of bamboo which allows the batteries to pass easily through it, cut it to about 17 - 18cm. in length.
2. Make the battery terminals as shown in the sketch 4.
3. Cut a slot in each side of the bamboo to take one of the terminals (see 'A' in sketch 3). Insert one of the cells and mark off the position for the second pair of slots (b). add a second cell and mark off the position for the third pair of slots (c). Remove the two cells and cut the slots.
4. Insert the terminals and cells and ensure that the terminals are firmly in contact with the cells.

Circuit for Use

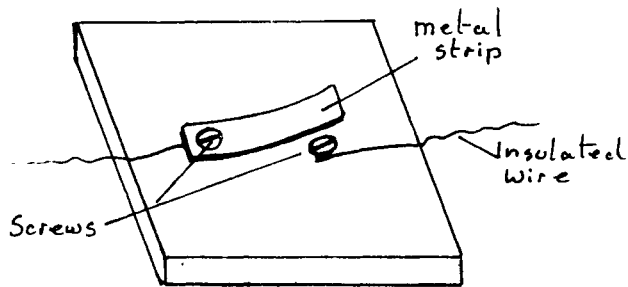
By joining the ends of the wires connect up the sockets, switch and battery holder as shown in sketch 5. The bulbs show light. If they do not check that:

- (a) Terminals are in contact with the cells. The negative one may require bending a little more to make a firm contact, or
- (b) Check that the terminals are not rusty where contact is made. Remove any rust by scraping with a knife or rubbing with sand/emery paper (this also applies to the switch).

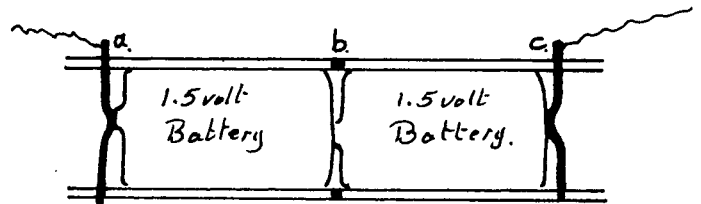
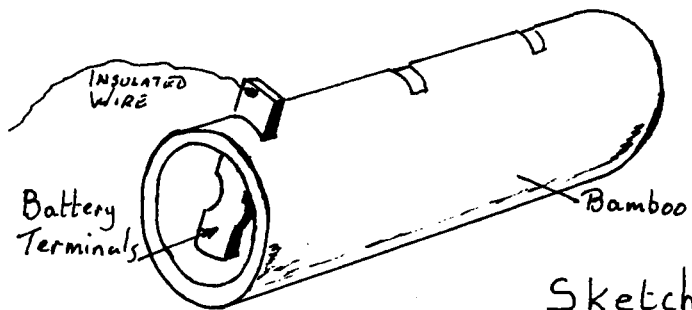
- (c) The bases of the bulbs in the socket are touching the tops of the brass screws beneath.
- (d) None of the wires is loose.



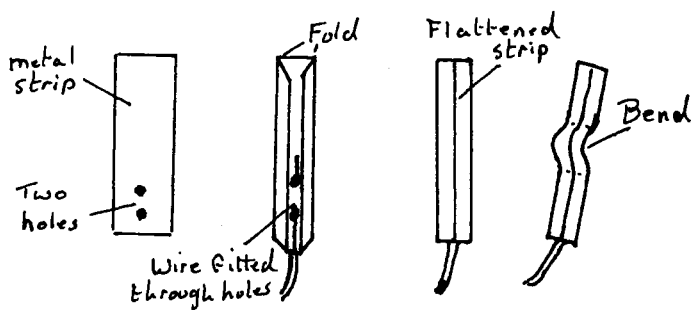
Sketch 1. BULB HOLDER.



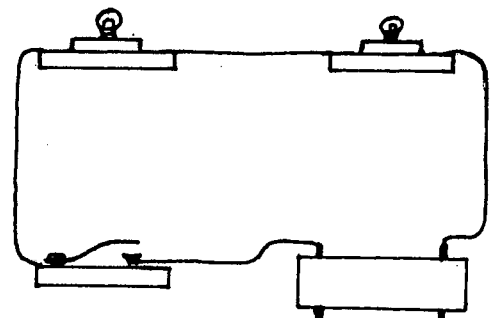
Sketch 2. SWITCH.



Sketch 3. BATTERY HOLDER.



Sketch 4. Making the Battery Terminals.



Sketch 5.
COMPLETED CIRCUIT

Group B.

Topic: EXPANSION

Sub Topic: Expansion of liquids

Materials needed

Two identical bottles of approximately 50cm.³ capacity, with screw-on caps.
Two empty ballpoint pen refills (or similar transparent tubes).
One liquid container with height greater or equal to that of the bottles.
Thin rubber strip (e.g. from a bicycle inner tube) to make the seal under the lids.

Cardboard, approximately 15cm. x 10cm.

Graph paper approximately 15cm x 10cm.

Piece of stick approximately 20cm. long to act as a stirrer.

Paper and glue.

Liquids to be compared, e.g. water and alcohol.

Construction of the Apparatus

1. Make a small hole in the lids of each of the two bottles so that the plastic tubes fit tightly into them.
2. From the rubber sheet cut two discs so that they fit tightly into the lids of the bottles. Make a small hole in these rubber discs such that the plastic tubes fit tightly into them. (These discs act as seals to prevent the escape of liquids).
3. Stick the graph paper onto the cardboard and, using small strips of paper, stick the plastic tubes evenly to the graph paper (see diagram).
4. Carefully fit the tubes into the bottles, having filled the bottles with the liquids to be compared. Check that the tubes are strong enough to support the cardboard, if not, construct a suitable additional support.
5. Place the apparatus in the water container, it is then ready for use.

Using the Apparatus

This apparatus can be made by a number of groups in the class with each group providing its own materials to do so. As with all apparatus, it is recommended that the teacher tries it out to observe any problems or difficulties.

1. Make sure that both tubes fit tightly into the caps and rubber seals.
2. Fill the bottles to overflowing with the chosen liquids. Screw on the caps so that (a) no leakage occurs, (B) a column of liquid appears in the tubes, (c) no air is trapped in the bottles.
- 3) If a leak appears where the tube enters the lid it can be sealed with mud, plasticene or candle wax. Alternatively a new rubber seal with a smaller hole can be used.

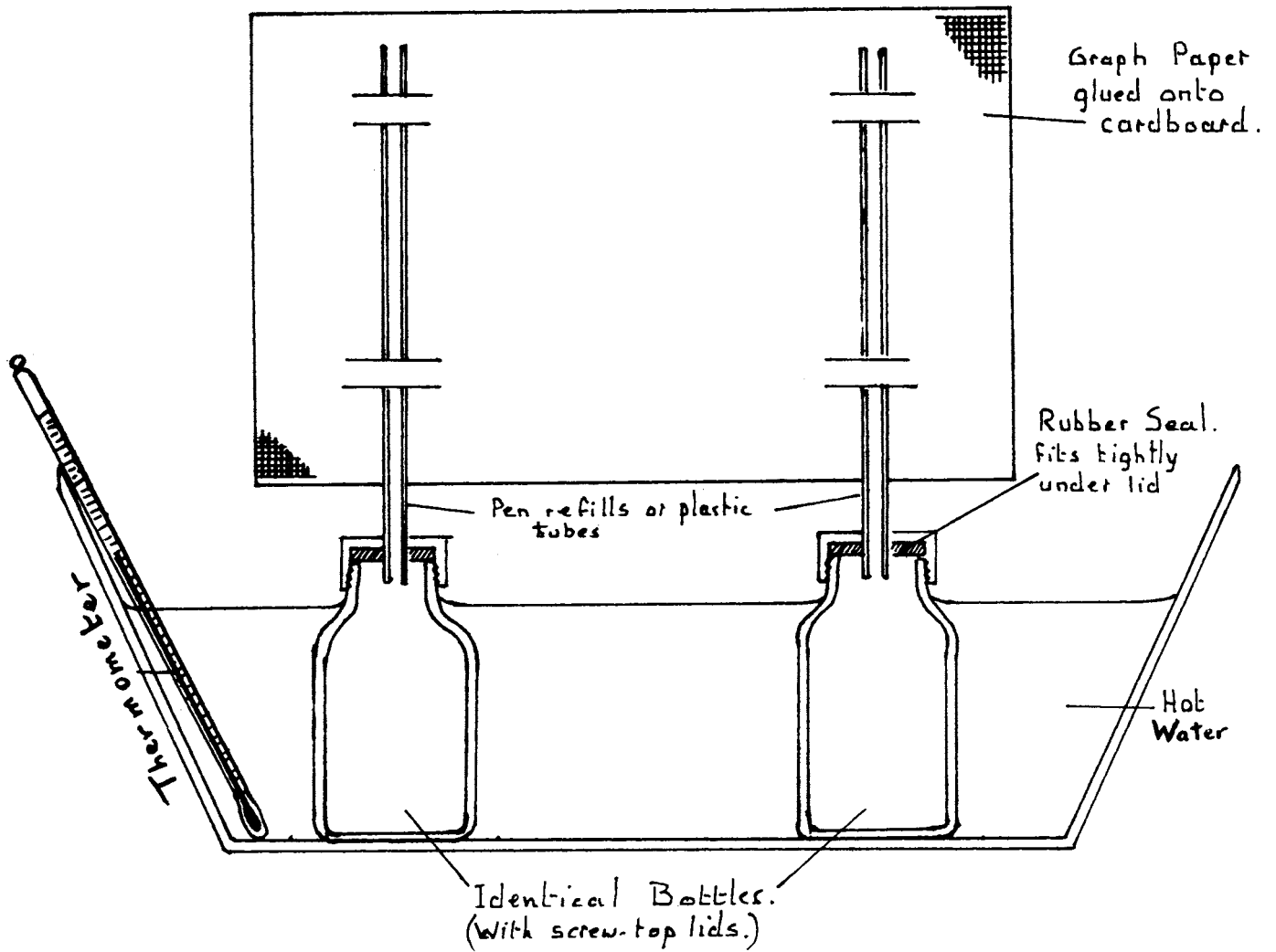
4. Ensure that the columns are initially the same height, if one is lower than the other an adjustment can be made by screwing the lid tighter on the bottle with the lower column.
5. Heat the water for the container in the sunshine until the group is ready to perform the experiment. Then place the bottles in the water stirring gently and continuously.
6. A single thermometer can service all groups by having each group request the thermometer only when they are ready to take the temperature reading.

Evaluation

The narrower the tube the greater will be the height of the liquid rise. If there is overflow from the top of the tube then the following modifications can be adopted.

Use a tube of larger diameter, e.g. plastic transparent drinking straw, or the transparent barrel of a ballpoint pen. (Seal side hole). Do not warm the water in the container so much.

All the apparatus used in this experiment except the thermometer, one of the liquids, the graph paper and the glue, are 'discards' hence it is possible to have many sets of the apparatus constructed.



Arrangement of Apparatus for Observing the Expansion of Liquids.

GROUP C.

Topic: ELECTROMAGNETISM

Sub Topic: To show a novel use of electromagnetism and demonstrate some practical applications.

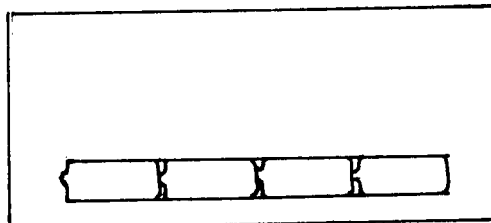
Materials Needed

Copper Wire (insulated)
Timber and board scraps
Tube - about 2 cm. diameter or paper and glue
1 rubber band
Nails
Tin can
Iron rod or bolt
Solder - if available
Tape - cello tape, insulation tape or adhesive tape, etc.
String
Dry cell batteries - 4 of 1.5 volt (large torch batteries, type D.)

Construction of the Apparatus (refer also to diagram)

1. Base

Obtain a piece of wood or ply about 30 cm. long by about 20 cm. wide. It must be about 30 cm. long so that the four batteries can be placed in series as shown here:



2. Support Stand

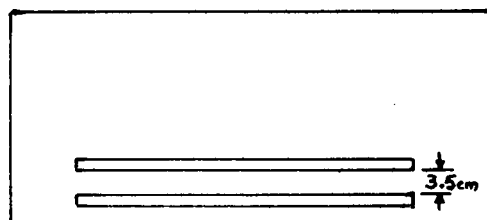
Any suitable piece of wood, e.g. 4 cm. x 2 cm. about 40 cm. long. This should be nailed to the base in the middle at the back edge so that it stands vertically.

3. Solenoid Support

Any piece of rigid metal, plastic, wood or plywood, (e.g. 3 ply 10 cm. x 2 cm.). It should be nailed to the support stand about 8 cm. above the base.

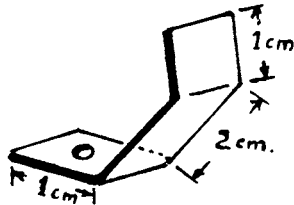
4. Battery Holder

Two pieces of wood about 2 cm. x 2 cm. and 24 cm. long. Nail them to the base so that they are 3.5 cm. apart and so that the batteries will fit in.



5. Battery Connectors

Cut two pieces of tin about 4 cm. long by 1 cm. wide. Bend them as shown below. With a nail or drill, make a hole in each. Nail one connector to each end of the holder so that they are 14 cm. apart. Place the batteries in and bend the connectors to suit. Solder the wires to the connectors; the wires can be nailed to the connectors if no suitable solder is available.



6. Switch

Cut strip of tin 1 cm. wide. Cut off two lengths, one 5 cm. long and the other 2 cm. long. Bend as shown below.



Connect wires with solder and secure with nails to the base. (Wire may be nailed under switch pieces if it is not possible to solder).

7. Solenoid

Solenoid about 2 cm. diameter and 8 cm. long.

PVC conduit or pipe, a length of thin-walled bamboo, or a cardboard tube. It is also possible to roll paper or cardboard into a tube and glueing or taping it together.

Details for winding the coil

Take about 50 cm. of 0.5 mm enamelled copper wire or cotton insulated wire or bell wire and:

- i) Leave about 10 cm. free at one end and tape the wire to the former about 0.5 cm. from one end.
- ii) Start winding the coil closely and wind until about 0.5 cm. from the other end.
- iii) Put on another two layers of turnings and tape the wire at the opposite end to the first tape. Leave about 10 cm. before cutting the wire.

The solenoid can then be tied onto its support with string, rubber bands or wire.

8. Hanging Rod

Iron Rod - a reinforcing rod from a building site or bolt with the head cut off. This should be about 15 cm. long and between 1.0 cm. and 1.5 cm. in diameter. Make sure it can fit loosely inside the solenoid.

Hanging Loop - Fix a loop at one end of the iron rod with wire or string so that a piece of rubber can be tied to it.

Rubber Band

Cut a medium sized rubber band and tie one end to the wire loop on the rod and the other end to the nail on the stand. Check that the rubber band can

stretch easily and that the iron rod moves easily through the solenoid. Also when the iron rod is hanging at rest the bottom should be just level with the bottom of the solenoid.

Large Nail (about 7 cm. long)

Nail this into the support stand at a convenient height depending upon the length of the piece of rubber. The nail can be bent so that the iron rod is centred in the solenoid.

Connecting the Circuit

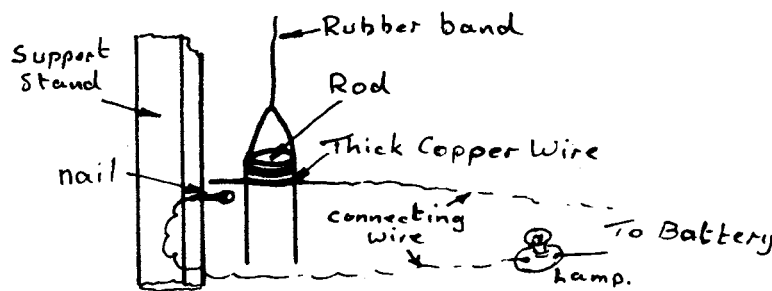
1. Connect one wire from the solenoid to the battery lead, and the wire from the other end of the solenoid to the switch wire.
2. Connect the other wire from the switch to the wire from the other end of the battery. The circuit is now ready for use.

Teachers Notes (Refer to the diagram)

- i) When the switch is pressed on the solenoid becomes magnetic and tries to draw the bar inside so that the middle of the iron bar is in the middle of the solenoid. The solenoid will pull the bar until the rubber band stops it going any further.
- ii) When the switch is then let off the rubber band will pull the rod up.
- iii) When the switch is pressed on and then let off repeatedly the rod will jump up and down.

Extensions

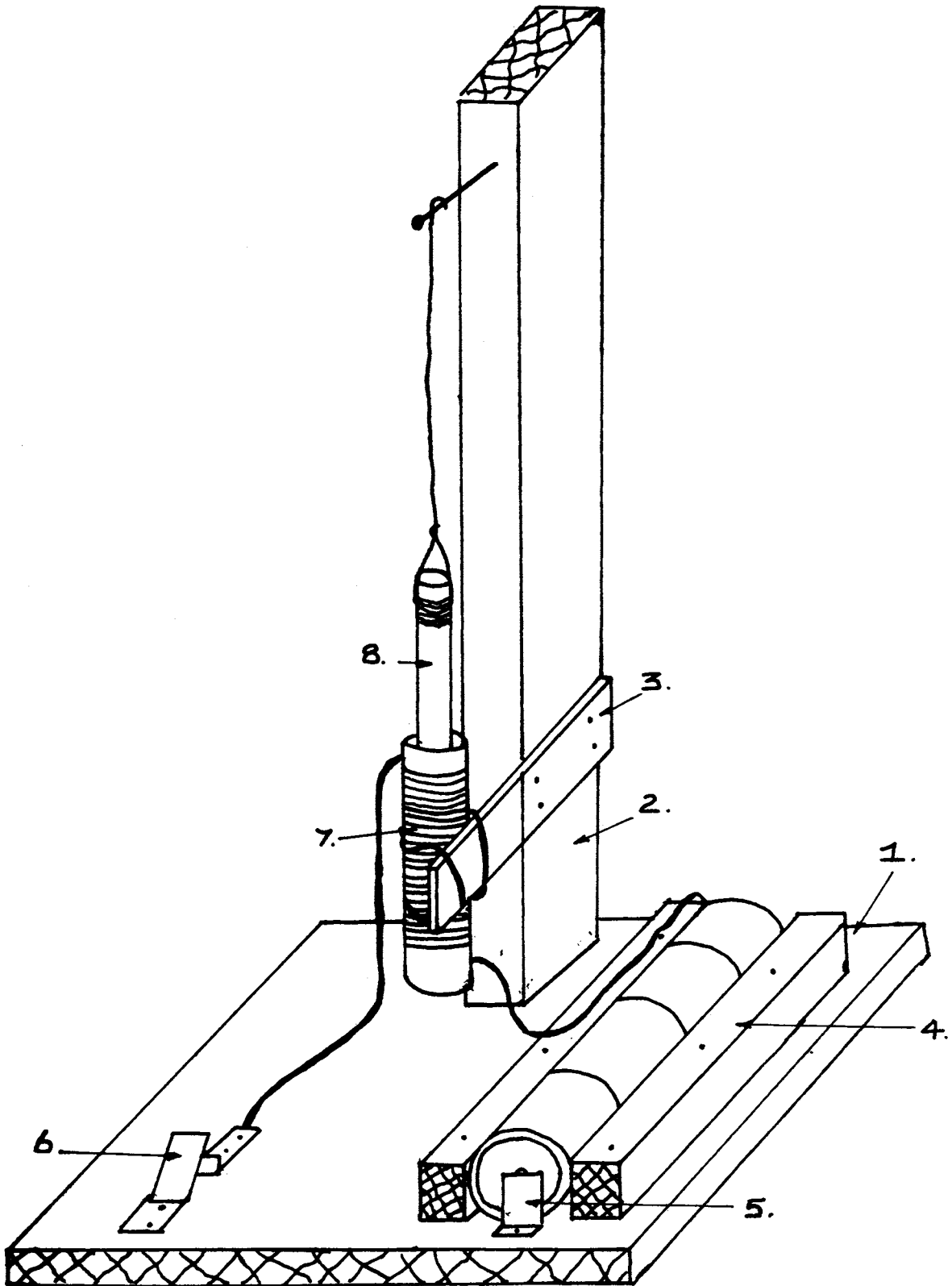
- i) This model can be related to the solenoid in a starter motor for cars and trucks which pushes the cog of the starter motor into gear with the flywheel when the key is turned on. A set of simple contacts could also be hooked onto this model to show how it can become an electrically operated switch as shown in the diagram. When the bar moves down, the circuit for the lamp is completed and the lamp will light up.



- ii) This device can also be used for picking up metal objects.

Place a few small nails under the solenoid. While the switch is pressed on pull the rod down until it touches the nails then slowly let it rise up. The nails will be lifted up too. Now let the switch off and most of the nails will fall off as the iron bar is no longer magnetised by the solenoid.

'Jumping Rod' Demonstration Apparatus.



GROUP C.

Topic: TRANSFORMATION OF ENERGY

Sub Topic: To design a low-cost prototype using readily available materials to illustrate the principle of a HYDROELECTRIC GENERATOR

Plan

The plan was to construct a turbine using a tin lid supported on a thin metallic rod as the axle. The turbine should be free to rotate inside a tin can, the axle passing through the centres of the closed end and the lid. A hole is to be cut out at a suitable place in the tin can for a water jet to strike the turbine blades. The turbine needs to be coupled with a generator (bicycle dynamo). A light bulb to be connected to the generator. Water entering the can through the jet strikes the blades and turns the armature. The current lights up the bulb.

Materials Needed

One metre hose (plastic or rubber tubing)
20 cm. plastic tubing (small)
One medium sized milk can (10 cm. length and 10 cm. diameter)
2 lids preferably off the same type of milk can.
One 1.5V bulb.
20 cm. insulated wire (2 pieces)
One 18 cm. metal rod.
One bicycle Dynamo (or generator)
One stand made of timber and plywood (50 cm. verticle timber and base - a flat piece of plywood/rectangular or square preferable.
One hammer
One soldering iron and lead (or use strong glue or Araldite)
One 7.5 cm. nail
One 1 cm. diameter pipe, one end squashed in.
One tin snip.
Nails and screws.

Construction of Apparatus

- a) Use a 7.5 cm. nail and with a hammer punch a hole through the centre of the bottom of the can and also in the centre of the can lid.
- b) Remove the lid of the can, and with a cold chisel and hammer (or tin snips) cut out the parts of the lid that are not required. The part that is to be cut out is marked in dotted line (See Sketch 2)
- c) Construct the support stand by nailing the 50 cm. upright to the base as shown in the diagram of the apparatus.
- d) Making the Water Wheel
 - i) Using tin snips reduce the diameter of the second lid. Make sure it is circular and will easily fit into the can.
 - ii) Mark a circle about 2 cm. diameter from the centre of the tin lid. Divide the lid into 16 segments and cut down the lines as far as the 2 cm. circle. (See Sketch 2.)

- iii) Punch a hole in the centre of the lid. The size of the hole should just fit the rod available for the spindle.
- iv) Now bend each of the segments in the same direction to form the wheel as shown in Sketch 2.
- v) Push the water wheel onto the rod bar a distance of about 3 cm. Solder (or use Araldite Adhesive) the wheel to the spindle.
- vi) Push the 2 cm. piece of small-bore plastic tubing (or similar spacer) onto the rod from the 3 cm. side and insert the rod into the can so that it protrudes through the bottom of the can by 1 cm.

e) Making the Jet

- i) Mark on the outside of the can the position of the wheel inside the can. Remove the wheel from the can.
 - ii) Punch a hole in the side of the can on this mark.
 - iii) Beat one end of the piece of metal tube to make it narrow so that water comes out as a narrow jet.
 - iv) Replace the wheel in the can. Fit the jet into the hole and adjust the angle of the tube so that when you blow into the tube the wheel rotates freely.
 - v) Having found the correct position, seal the tube into the can with solder (or Araldite).
- f) Place another piece of small-diameter plastic tubing onto the top of the spindle and cut to a suitable length so that when the lid is inserted over the spindle it fits back into position in the can.
- g) Solder (or Araldite) two lengths of tin onto each side of the can. The can may now be fixed to the upright of the stand by nailing through these metal strips. The lid of the can facing downwards.
- h) Using suitable fixings mount the bicycle dynamo onto the stand. Before firmly fixing connect the dynamo spindle to the spindle of the water wheel with a short length of plastic tubing. This connector must be straight and not bent in any way. Adjust dynamo fixing to correct position and firmly fix in position.
- i) Mount a bulb holder on the top of the support stand and connect to the dynamo. Screw in a 1.5 volt bulb.

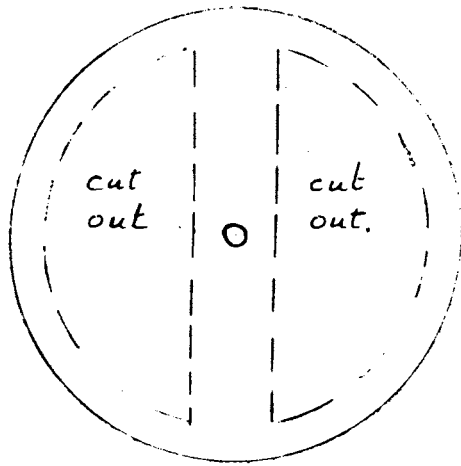
j) To use the Apparatus

Attach the long hose to the metal tube and connect the other end to a water tap. The apparatus should preferably be stood in a sink. Open the tap and give the dynamo a little turn and it should start to revolve. The speed depends upon the water pressure. The lamp should light when the wheel turns the dynamo.

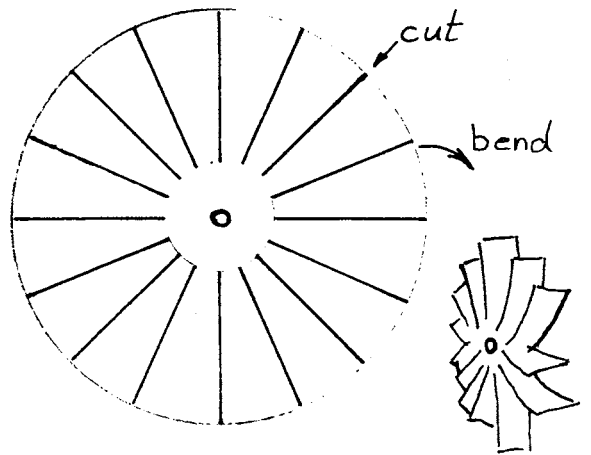
NOTES

- a) Care should be taken while fixing the tube to the tin so that a proper angle is maintained to ensure the striking of the water jets on the correct side of the blades.
- b) The coupling between the turbine disc and the dynamo must be aligned straight to ensure free rotation.

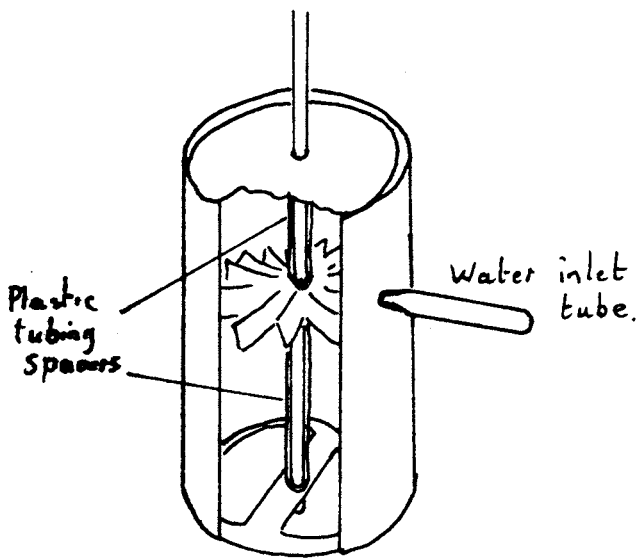
- c) If a bicycle dynamo is not available, a suitable generator can be substituted.
 - d) The current can be used to light a lamp or ring a bell or buzzer.
 - e) Change the water pressure and observe the changes in the brightness of the bulb.
 - f) While the dynamo is running, disconnect the bulb and observe the change in the speed of rotation. Connect the bulb and notice the change.
2. This apparatus is designed to demonstrate the transformation of energy in grade 8 unit, force, work and energy. With this design it is envisaged that the teacher will be able to demonstrate the concept of energy being transferred; using this apparatus, of course, to illustrate water energy converted to light energy (electricity) mechanical energy - electrical energy - light energy.



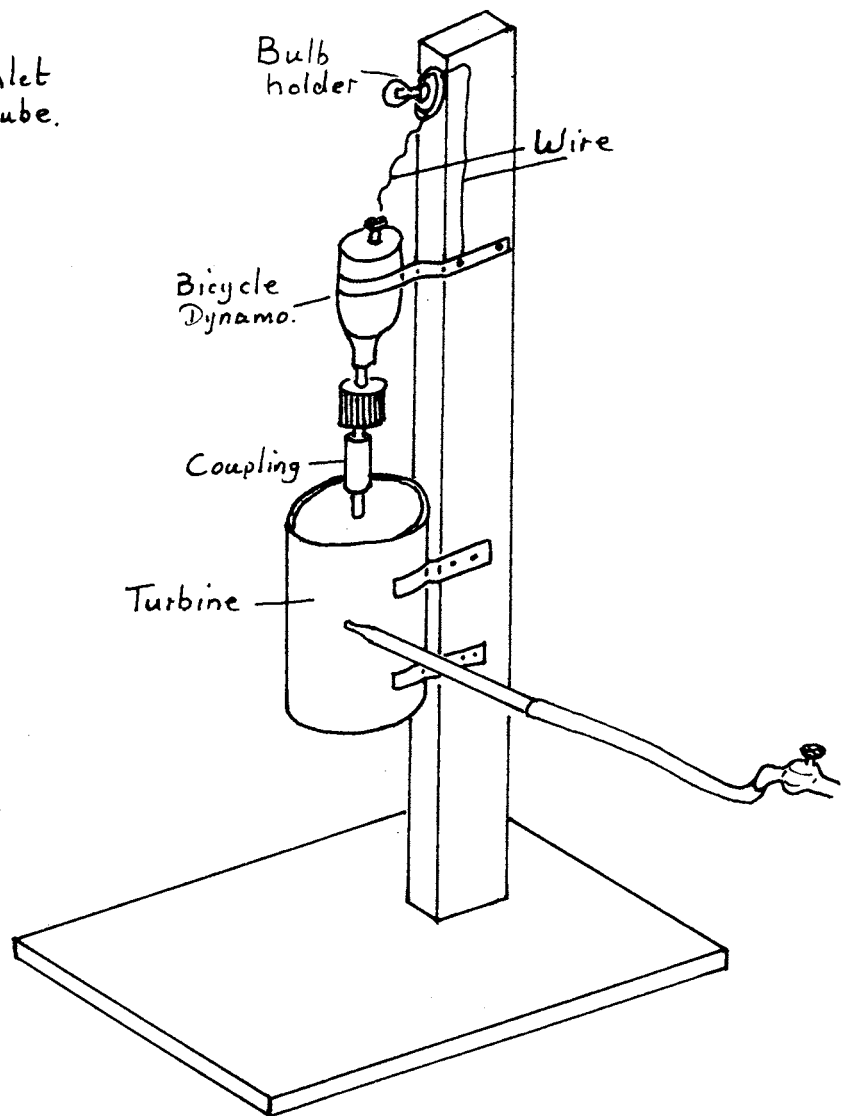
Sketch 1.



Sketch 2.



Turbine Arrangement.



Hydro-electric Generator.

GROUP E.

Topic: ELECTRICITY

Sub Topic: The Operation of an Electric Buzzer

Materials

One large piece of plywood (15 cm. x 12 cm. x .9 cm.)

Enamelled Copper Wire (2½m)

2 pieces of Plywood (3 cm. x 3 cm. x .9 cm.)

One large nail (6 cm.)

6 small nails (2 cm.)

4 Screws (2 cm.)

4 Metal strips (5½ cm. x 1½ cm.)

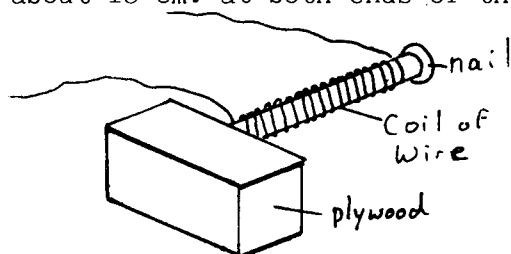
1 tin strip (6 cm. x 1 cm.)

1 Contact (adjusting) screw (3 cm.)

1 Dry Cell (1.5 v)

Electro-Magnet

1. Take one of the small pieces of plywood (3 cm. x 3 cm. x .9 cm.) and hammer in the large nail (6 cm.) through its centre, leaving about ⅞ of the nail out.
2. Wind the long piece of wire around the nail (following one direction only) leaving about 15 cm. at both ends of the wire.



3. Nail this piece of plywood onto the large-size piece of plywood - the base for the buzzer. Use two small nails.

4. Battery Holder

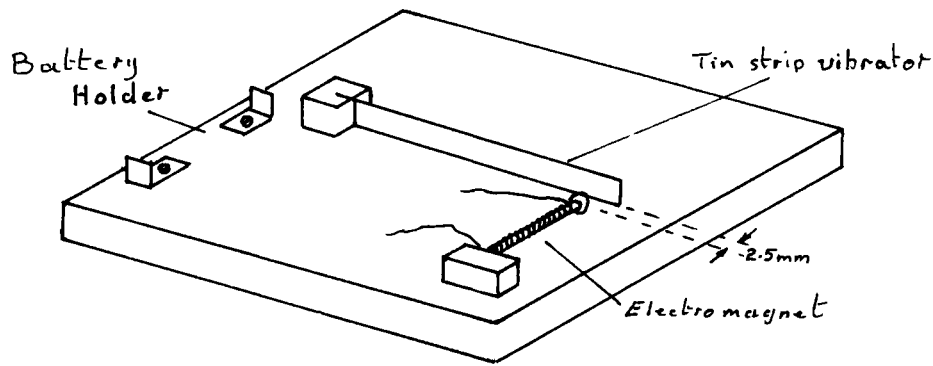
Take two of the metal strips and bend each of them at the middle into a right angle.

5. Make a hole at one of the ends of each metal strips. (The hole should fit the wood screws)
6. Screw these metal strips onto the base as shown in the diagram. They must grip the dry-cell firmly.

7. Vibrator

Make a cut at the other small piece of plywood to fit in one end of the tin strip. Glue the tin strip into place if it is not very firm.

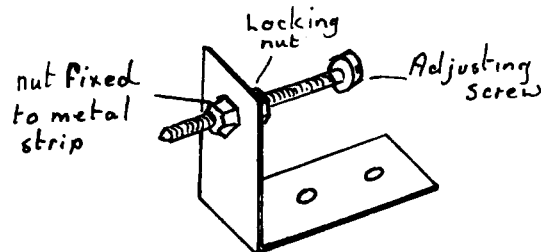
8. Nail the piece of plywood attached to the vibrator. See diagram. (The end of the tin strip should be 2.5 mm. away from the electromagnet.)



9. Contact Point

Get the other metal strip and bend it into a right angle.

10. Make a hole on one of the ends of the metal strip. It should fit the adjusting screw.
11. Solder one of the nuts on one end of the hole. The nuts hole and the other hole should be in line.
12. With the other nut on the other side of the hole, screw the adjusting screw in.

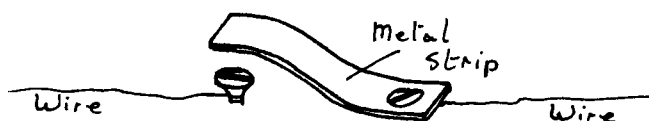


13. Nail the above part in place onto the base. The tip of the adjusting screw should be just barely touching the vibrator.

14. Tap Key

Bend the last metal strip into the shape shown and make a hole at one end to fit in the wood screw.

15. Screw the metal strip onto the base using a wood screw.
16. Using another wood screw, screw into the base but at a position under the free end of the metal strip. This is the switch.

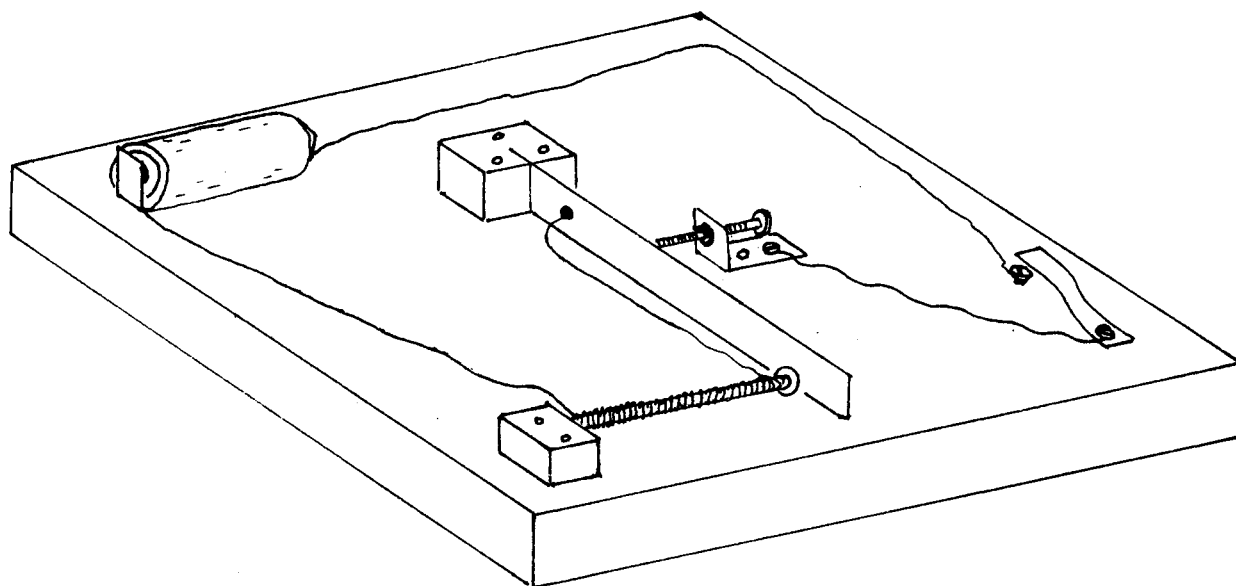


17. Wiring

Use solder to join your wirings. See the diagram for wiring connections.

To Operate Buzzer

Press the tap key after placing the dry cell in the holder and see whether your buzzer works. If it does not, adjust the contact point by either tightening or loosening the adjusting screw.



Arrangement of Apparatus for the Electric Buzzer

GROUP E.

Topic: ELECTRICITY

Sub Topic: A simple electric motor

Materials Needed

1 Baseboard approximately 20 cm. x 10 cm. x 1 cm.

3 nails x 7 cm.

1 nail x 15 cm.

2 screws x 4 cm.

2 screws x 2 cm.

Glass rod. 5 cm. long x 0.7 cm. diameter

Cork 3 cm. x 3 cm.

Insulated Wire (approx. 24 guage)

Instructions for Assembly

1. Drill a small hole through the centre of the base board and drive a 7 cm. nail through it from the underside. Cut the end off the nail so 5 cm. is protruding through the wood. Drive the other two 7 cm. nails into the baseboard and screw the screws into place as shown in Sketch 1.
2. Wind 200 turns of insulated wire on the two nails leaving about 15 cm. of free wire at each end. The wires from the beginning of each coil are soldered to the small screws. The free end of each coil is now wound several times around the screws and bent so that it rests in contact with the centre nail. The insulation must be removed for 1 cm. either side of the contact point (see Sketch 2).
3. Constructing the armature: Drill a .5 cm. hole halfway through a cork and fit the piece of glass tubing into the hole. Force a 15 cm. nail through the top of the cork. (Or use two 7 cm. nails) Wind 200 turns of insulated wire onto each end of the nail as shown in Sketch 3.
4. To construct the commutator take two pieces of thin sheet copper or tin 1.3 cm. x 1.0 cm. Bend them to fit around the glass tubing so there is a 3.4 mm. gap between them. Solder one of the armature wires to each and then bind the commutator plates into position top and bottom with adhesive tape.
5. Place a washer over the centre nail and set the armature on the centre nail so the brushes make contact with the commutator. Turn the glass tube in the cork until the brushes lie across the gaps in the commutator when the armature is in line with the field magnets.
6. Now connect the motor to some dry cells. About 6 - 9 v. will be required. Give the armature a spin and it should continue to rotate.

NOTE: If the motor does not run smoothly you may have to:

- a) adjust the contact of the brushes with the armature.
- b) check and adjust the position of the commutator.
- c) balance the armature.

If the motor does not run at all check carefully all the wiring in accordance

with the diagram.

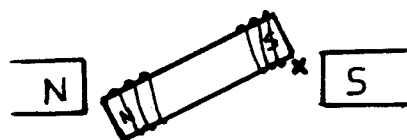
FUNCTIONING OF AN ELECTRIC MOTOR

The teacher should become familiar with the operation of an electric motor. A brief explanation is given below.

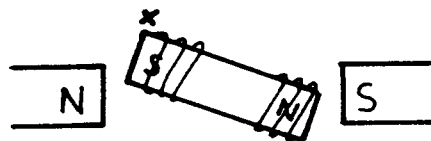
An electric motor consists of a rotating electromagnet, (called armature) and two fixed magnetic poles which may be permanent magnets or electromagnets. When a current is passed through the armature it becomes an electromagnet and is attracted (or repelled) by the fixed magnetic poles causing it to rotate. Each time the armature rotates 180° a device (called a commutator) reverses the current direction in the armature enabling it to rotate continuously in one direction.

In the diagrams to follow point X serves as a reference point on the armature.

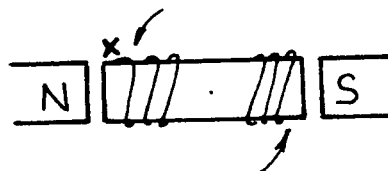
1. If the current in the armature is switched on in the position the armature would begin to rotate in an anti-clockwise direction since like poles repel.



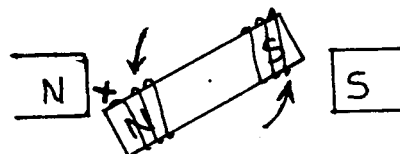
2. After rotating 90° the unlike poles are beginning to attract; causing the armature to continue to rotate anti-clockwise.

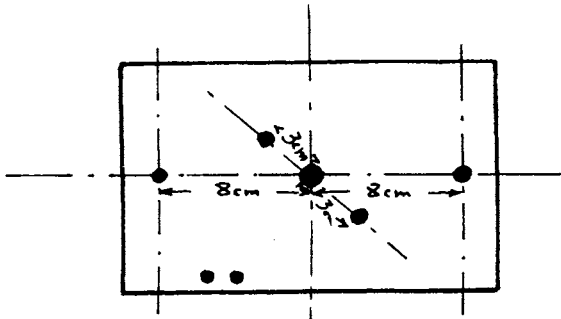


3. As the armature passes between the fixed poles the commutator reverses the direction of the current in the armature and hence the poles repel, and the armature continues to move in an anti-clockwise direction.

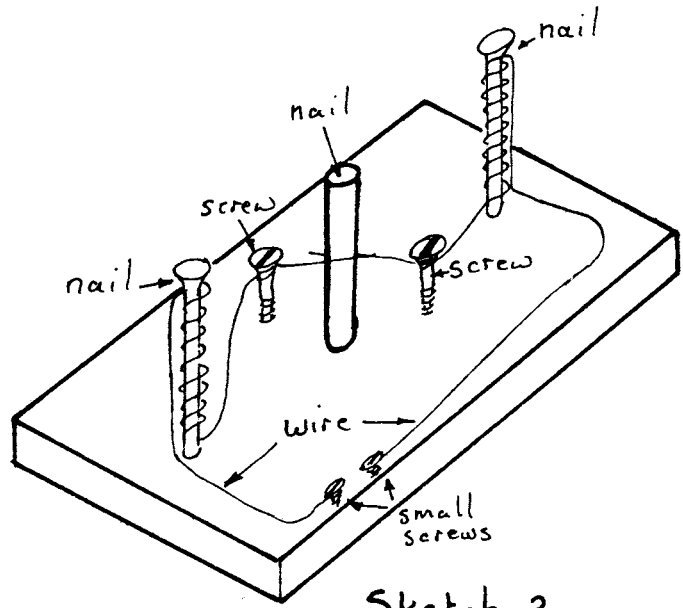


4. After rotating a further 90° the poles of the armature are attracted. The attraction of unlike poles now causes the armature to continue rotating in an anti-clockwise direction.

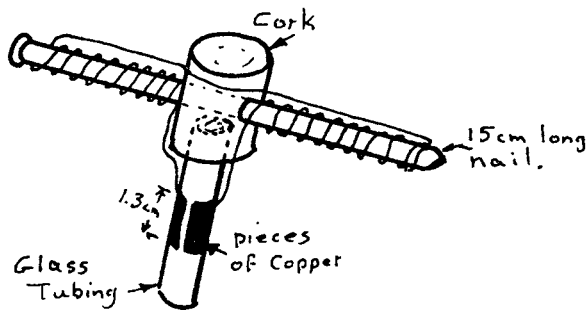




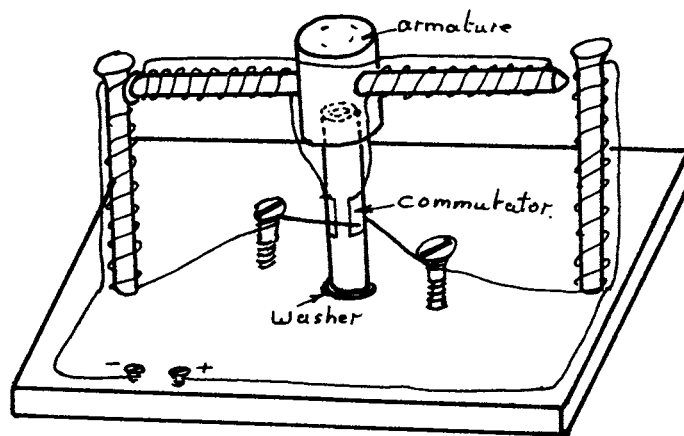
Sketch 1.



Sketch 2.



Sketch 3.



Sketch 4.

A Simple Electric Motor.

GROUP E.

Topic: ELECTRICITY

Sub Topic: Detection of induced current (Electro-Magnetism)

Materials Needed

Flat Wood (Plywood)
4 Woodscrews
1 Match Box (inside only)
Copper Wire (3 metres)
Sticky Tape (Cellotape)
1 Magnetic Compass (to fit into match box)
Bamboo
6 Nails (2 cm.)

Construction of Apparatus

1. Base

Cut a piece of suitable wood (plywood) to approximately 25 cm. x 8 cm.

2. Compass Mount

Cut a piece of suitable wood (plywood) to approximately 5 cm. x $3\frac{1}{2}$ cm. to fit into the matchbox. Make a hole in the wood of approximately 2 cm. diameter so that a plotting compass can be fitted into the hole. Insert the wood and compass into the matchbox. Using the sticky tape, tape the wooden block to the matchbox.

3. Compass Coil

This coil is made of a few turns of copper wire, and wound carefully in one direction only. The coil should be taped to the box to prevent it springing apart. Bare the two ends of the wire for later connections. Fix the whole arrangement (current detector) to the base at one end (see diagram)

4. Magnet Coil or Solenoid

Cut a piece of small diameter bamboo to a length of about 4 cm. (the diameter should be of size which is able to allow an available magnet to pass into it). Wind the copper wire onto the bamboo (about four layers) and leave a length of about 10 cm. of wire from each end of the coil. Fix the coil to the other end of the base board using the small nails or screws (see diagram)

5. Switch (This can be omitted from the apparatus)

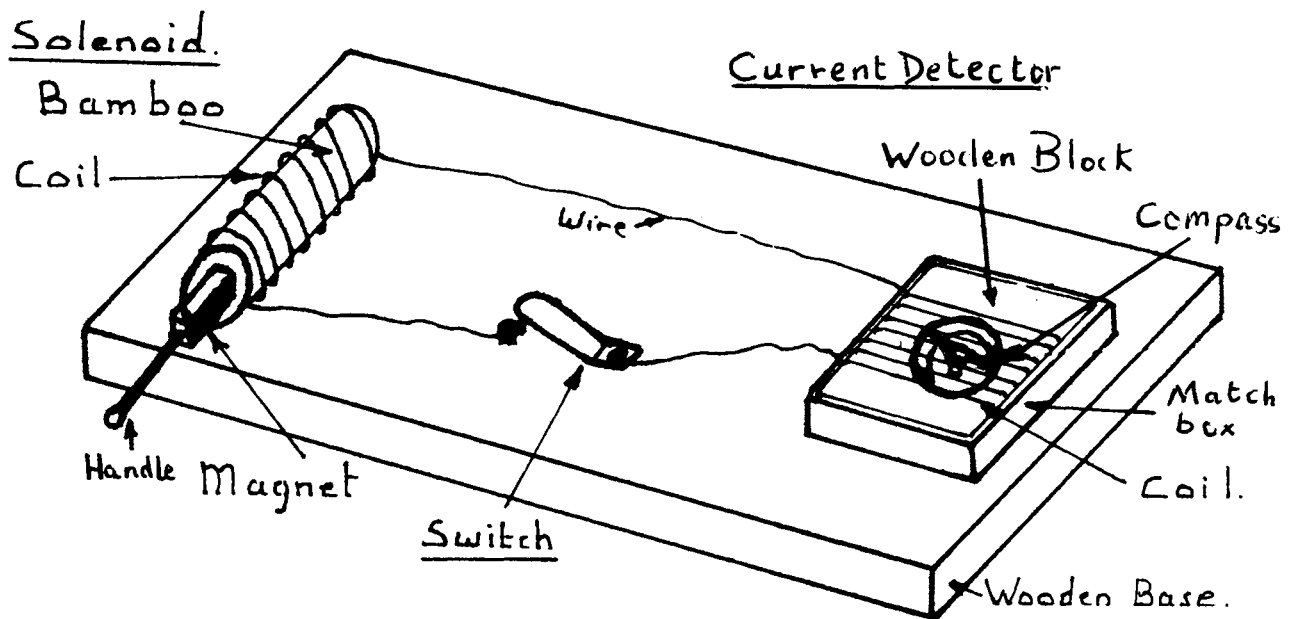
Take a piece of metal strip and make a small hole in one end. Using the small screws, pass a screw through this hole and wrap one of the bare ends of wire from the compass coil around the screw. Screw this screw into the base at a suitable position. Using a second screw (or nail) connect one bare end of wire from the solenoid to the screw and screw it into the base in a position where the metal strip can touch it if

if pressed down.

6. Connect the wire from the other end of the solenoid to the lead from the compass coil (current detector).

7. Operation

When a magnet is moved into and out of the solenoid there should be a deflection on the compass needle indicating that an electric current has been induced in the circuit.



A Simple Electric Current Meter.

GROUP D.

Topic: LIGHT

Sub Topic: Pinhole Camera

Materials

Various size tins, e.g. milk tins
Plain Paper, Newspaper
Rubber band
Cardboard
Oil, i.e. cooking oil, motor oil.
Black paper

Alternatives:

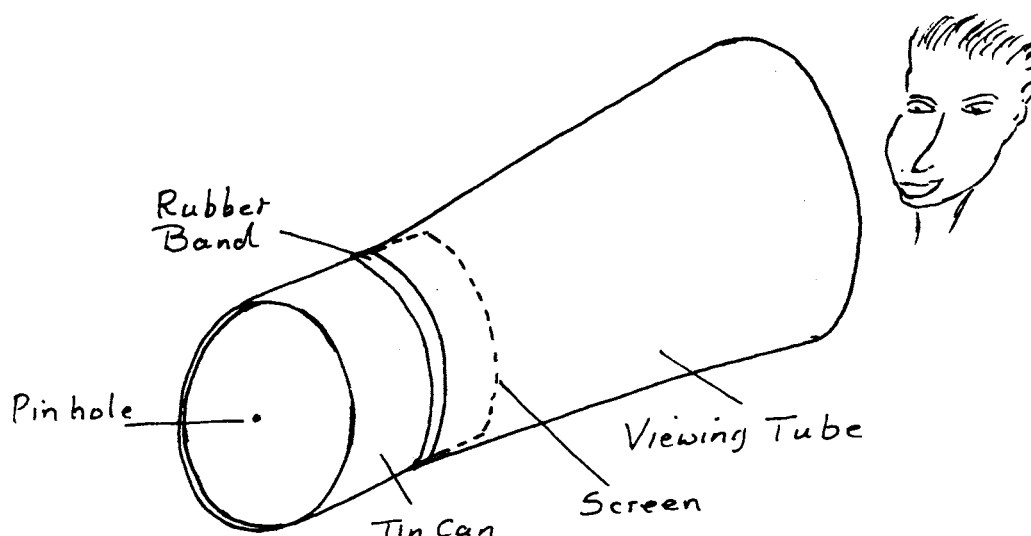
Length of bamboo
Stone or any object to hit with
Tissue paper
Sticky tape, string, vines
Newspaper, plastic, banana leaf
Black paint, Black texta, charcoal

Construction Details

1. Make a nail hole in the middle of the bottom of the tin.
2. Blacken inside of the tin, using paint or charcoal.
3. Fix a screen of greased or oiled paper, or plastic, over the open end of the tin with an elastic band or sticky tape.
4. Make a viewing tube of cardboard or newspaper and put your eye to the open end.

Teachers Notes

1. Camera works best if you are inside the classroom looking at a bright object outside.
2. Camera works best when the inside of the tin is blackened.
3. Experiment with different sized holes. If the hole is too small the image will be dim. If the hole is too large the image will not be clear.
4. The best screen is thin paper with some oil rubbed on it.
5. Two holes will give you two images.



GROUP D.

Topic: LIVING AND NON LIVING THINGS

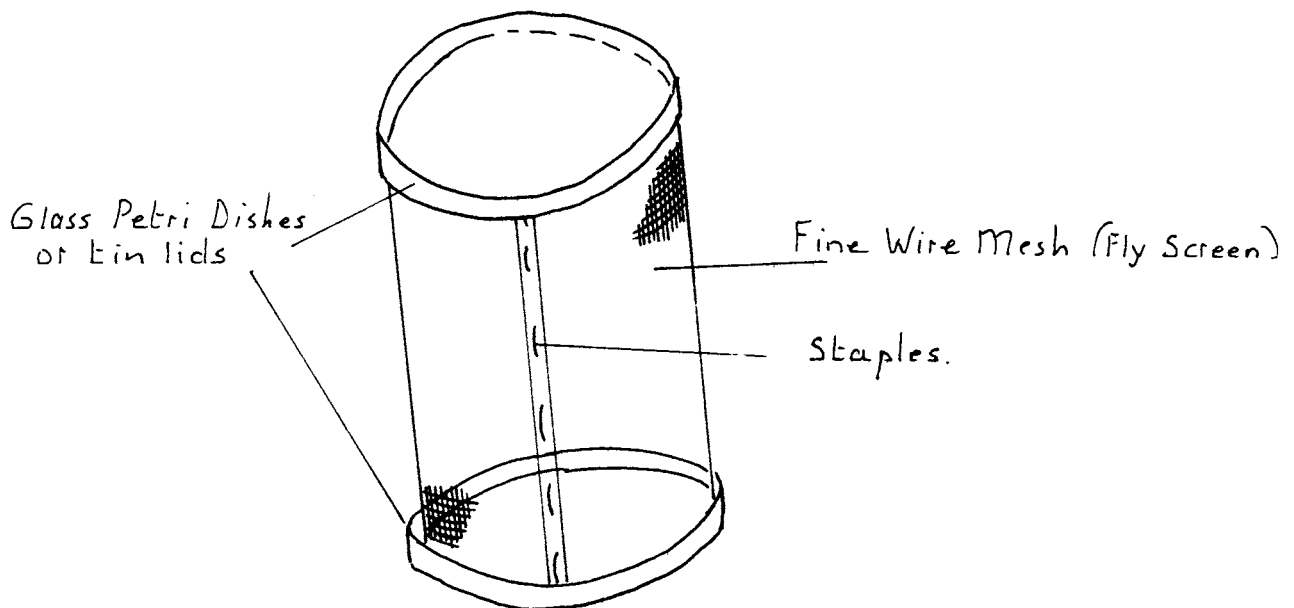
Sub Topic: To construct an insect cage

Materials

Two tin lids of the same size, or two petri dishes
Fine mesh wire or plastic sheet
Staples or sticky tape

Construction Details

1. Using the fine mesh wire make a cylinder which will fit snugly into the lids at either end.
2. Staple the cylinder to hold its shape or use the sticky tape.



GROUP D.

Topic: TRANSPIRATION

Sub Topic: To construct a potometer

Materials

Wood for base and sides

Ruler (wooden or plastic) or any means of measurement

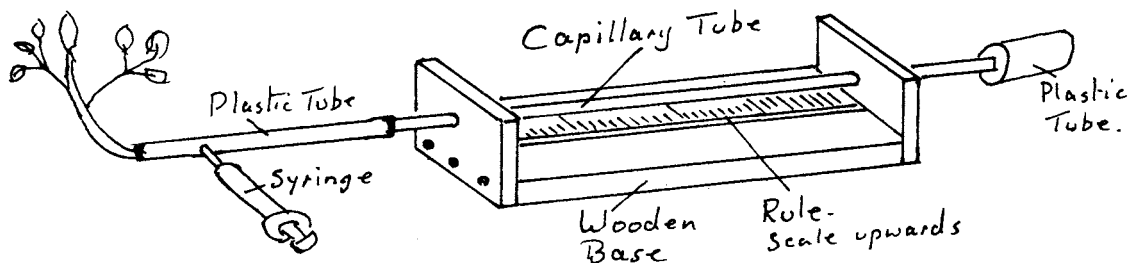
Capillary tubing glass (at least 150 mm. total length)

Two pieces of rubber tubing (at least 10 cm. total length)

One Syringe (20 cm³)

Construction Details

1. Cut wooden base to length and width 25 mm. x 150 mm. x 200 mm.)
2. Cut board to fit base. (see diagram)
3. Cut appropriate length of ruler to fit base and glue to base and allow to dry.
4. Drill holes of correct diameter and position for capillary tubing to fit. Tube must extend past end boards at least 30 mm.
5. Cut capillary tubing and fire polish ends.
6. Screw and glue end boards to base.
7. Gently push capillary tubing through holes into position.
8. Place tubing over ends of capillary tubing.
9. Insert syringe into rubber tubing at end which plant will fit.



GROUP D.

Topic: SPIRIT BURNERS

Sub Topic: Storage of apparatus

Materials Needed

Pieces of suitable wood

Nails

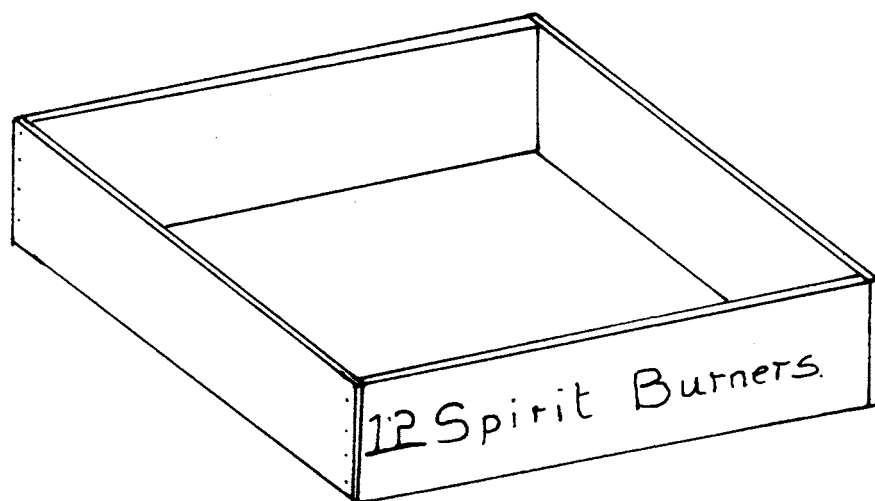
Hammer or stone

Sandpaper

Construction Details

To make a storage box for your burners decide on the number of burners you wish to conveniently store in one box. Work out the size of the box necessary to store these burners and cut the pieces of wood to make the box. Remember to make the height slightly higher than the height of the burners. Nail the sides and the base together and sandpaper to box to remove rough edges.

Note: The purpose of such a box is to provide safe storage for apparatus and readily identify if any items are missing at the end of practical sessions. This idea can be used for a wide range of pieces of apparatus.



AN EXAMPLE OF A BASIC KIT OF TOOLS FOR CONSTRUCTING
LOW-COST SCIENCE TEACHING EQUIPMENT

BITS, DRILL, TWIST, SET OF 13. High speed, round shank. For use in 3-jaw chuck. Set contains 13 bits, viz 4 of 1/16, 4 of 3/32, 2 of 1/8, 1 each of 3/16, 7/32, 1/4 inch. (For wood or metal. To fit in 40 380 00 DRILL...)

BLADES, HACKSAW, 30 CM. (Approx.). Low tungsten steel. Package of 12.

BLOW TORCH. Pump action pressure type. 2 pint. With kit of spares. (Blow Lamp).

BRADAWL, 5 CM BLADE. (M). Round pattern, beech handle. (For making rough round small holes in wood such as for starting screws, etc.)

CLAMP, C, 75 MM OPENING. (M) (Approx.). To act as simple vise to hold work.

CUTTER, GLASS, SINGLE WHEEL TYPE. With tungsten carbide wheel. (For cutting sheets of glass.)

DRILL, HAND; CAPACITY 1/4 INCH (6MM). Double pinion, with three-jaw chuck. = Stanley (UK) No. 803. (Needs BITS, DRILL ... 40 106 00).

FILE, ROUND, MACHINISTS, 15 CM. (Approx.). Smooth cut.

FILE, TRIANGULAR, 12 CM. (M) (Approx.). Single cut, extra slim, taper. (For cutting glass tubing.)

HAMMER, NAIL 225 G. (M) Bell face, with curved claw. Head approx. 225g. (Light carpenters hammer with claw to draw out nails.)

HAMMER, NAIL, 450 G. Bell face, with curved claw. Head approx. 450g. (Carpenter's hammer with claw to draw out nails.)

NAILS, WOODWORKING, ASSORTED. (M) Up to 64mm. Round wire with flat head. In package of approx. 500g.

PLIERS, ELECTRICIANS, 15 CM. (M) (Approx.). Insulated handles. With wire-cutter.

PLIERS, SLIP JOINT. Side wire cutting, approx. 19 cm with two joint positions.

RULE, STEEL, 12 INCH. Grad in cm and mm. Also in 1/16, 1/32 and 1/64 inches.

SAW, HACK, ADJUSTABLE, FRAME ONLY. To take blades of 25 or 30 cm. (Needs 40 151 02 BLADES).

* The following has been taken from the Unicef Publication - Eve Science Revision 2. The Second Revision of the Science Teaching Sections of Unicef Guide List "Eve" published in 1973.

If a school has no laboratory or similar adequate working space given over to science with a suitable cupboard and bench usable for constructional work, then only the simple tools marked on the list by an (M) for minimal, should be requested.

SAW, HACK, JUNIOR, (M) Blade length approx. 15 cm. Overall length approx. 25cm. Depth between blade and bow approx. 5 cm. = Gleave No. 14 J. (Versatile small saw for wood, metal, plastic, etc.)

SAW BLADES FOR JUNIOR HACK SAW. (M) 15 cm long with pinned ends. In package of approx. 12.

SCREWDRIVER SET, STANDARD, 5-PIECES. (M) Chrome-vandium alloy steel blades. Plastic handles. Shafts approx. size in mm (l x dia) 200 x 10, 150 x 8, 100 x 6, 80 x 5 (Electrician's type), 40 x 6 (Stubby size).

SCREWS, WOOD, CSK, 19MM NO. 4. In package of gross.

SCREWS, WOOD, CSK, 19MM NO. 6. In package of gross.

SCREWS, WOOD, CSK, 32MM NO. 8. In package of gross.

SCREWS, WOOD, CSK, 38MM NO. 10. In package of gross.

SNIPS, TIN, STRAIGHT BLADE, 3 INCH CUT. (M) Approx. 8 cm cut. Overall length approx. 20 cm. (Very useful for making articles of tin rejected from kitchen etc. in conjunction with soldering iron.)

SOLDER, TINSMITH, SOLID WIRE. In approx. 450g pack. For use with SOLDERING IRON. (Needs 51 698 03 SOLDERING PASTE.)

SOLDERING IRON, ELECTRIC 110V 160W.

SOLDERING IRON, ELECTRIC 220V 160W. (Alternative to 110V item).

SOLDERING IRON, NON-ELECTRIC. Weight of head approx. 250g. Copper. Complete with handle (Soldering Copper). (To be heated over a gas flame or in a clean fire or with Blow Lamp or Bunsen Burner.)

SOLDERING PASTE. Approx. 100g in can. (Flux) (Suitable for tin, but not for electronic work nor for zinc coated iron.)

SPANNER SET, BOX 0 TO 10 BA. 6 Spanners, viz 0, 2, 4, 6, 8 & 10 BA with tommy bars. = Buck & Hickman set 53B.

SQUARE, CARPENTERS, COMBINATION. 30 & 45 deg. adjustable approx. 12 cm blade graduated in inches and cm. = Stanley 122.

WRENCH, ADJUSTABLE, 20 CM. American pattern, rounded head. Forged steel.

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