PROTOTYPES, MODELS, EXPERIMENTAL DESIGNS AND MASS PRODUCTION OF EQUIPMENT

Participants at the 1976 Bahamas Workshop judged it premature to discuss the establishment of a Caribbean-wide mass production unit. Even national mass production does not yet exist, although the idea has received some consideration. While local mass production is unlikely to result in mass financial savings, there would be other benefits, some of which will be mentioned below. This section outlines some investigations into the possibility of mass production, together with designs and activities which could provide a foundation for, at least, mini-mass production.

In Jamaica, discussion among members of the Ministry of Education, the Science Education Centre and the plastics manufacturers revealed that the cost of moulds would be prohibitive. Once the national educational needs were satisfied, the moulds would be redundant, and it was concluded that local plastics production for schools was out of the question (4). This is disappointing; much of the landed cost of imported apparatus arises from shipping charges on bulky and fragile equipment. Laboratory glassware is both bulky and fragile, and at least some of it can be replaced by versions in plastics, whose bulk in the raw state is small. For primary school children, learning materials in plastics versions are most attractive. A regional or international mould-sharing enterprise seems worthy of very serious consideration.

Guyana approached the issue of local production through teacher workshops. The Ministry of Education, Social Development and Culture has a very clear policy of teacher development through the encouragement of teacher creativity in workshops. Whether teachers' equipment designs will lead to feasible mass production is an issue secondary to the personal growth of the teachers as they go through the experience of designing the equipment and constructing a prototype. This philosophy lay behind the workshops of 1977 and 1979, supported by the Commonwealth Secretariat and the British Council. Significantly, the workshops were named Teacher Vacation Courses (TVC), and according to Dalgety and Farley (1979) the evidence was that participants did gain confidence in teaching integrated science for CXC.

Participants at these workshops were drawn from laboratory assistants, industrial arts technicians and teachers of science and industrial arts in primary, community high and secondary schools (5). Special emphasis in the 1977 workshop was laid on the fact that participants should learn to use a certain number of tools and, apparently for this reason, the 1977 workshop was judged especially effective. The cross-disciplinary nature of the participants was supposed to lead to in-school co-operation, although whether this actually took place is not known. The substitution of local resources for materials used in imported designs was an aim of the workshops; Guyana, unlike the Turks and Caicos for example, has a large timber industry, and it was thought likely that some designs could be modified to use wood instead of metal.

The products of the 1977 workshop are listed in Appendix 1. Aware that prototypes must be evaluated over a period in schools, the organisers made no claims that these were models. Although feedback about such evaluation is not available, design of equipment for the community high schools has continued in the hands of an educator with carpentry skills, teacher training and a science degree. Meanwhile, the 1977 course co-ordinator, a physics teacher (6), has returned home after receiving further experience in Britain, to lead prototype production. An Equipment Production Centre is planned, although it is unclear whether the activities of this centre will be confined to promoting in-school production or whether it will attempt to provide a design base for mass production. (7,8).

In Trinidad and Tobago, local production of equipment for secondary school science is unlikely, at least in the near future. Research and development is expensive and can be best afforded by firms with world-wide markets. When a country has foreign exchange to spare, as Trinidad and Tobago has, the most effective stimulus to child-centred learning of science may be the ready provision of the best designs from abroad. A sudden expansion in 1975 of upper secondary education brought so much good imported equipment that teacher development activities could focus on the educational opportunities provided by these. And for the small islands, local equipment production for secondary schools would appear to be a most expensive proposition.

At the primary level, however, the numbers of children who are, or should be, learning science are so large and the research and development problems are so relatively small that local production deserves some consideration. At least in Trinidad and Tobago, this issue is under consideration by the developers of Science - a Process Approach for Trinidad and Tobago (SAPATT), (9). Among the most difficult problems facing designers of science apparatus are considerations of safety of children and apparatus. Especially risky are chemicals, electricity and fire, and primary science does not need to make much use of these.

There are also good educational reasons for encouraging teachers to depend mostly on common materials, and Warren and Lowe (1975) make a special point of this. In the Eastern Caribbean the trend is towards an environmental approach to primary science education (3), the successful Rural Education and Agricultural Project (REAP) of Belize, outlined by Raymond (1979, 1980), being a well-known example.

Whether or not go in for local production is not simply a cost issue. Below are outlined some designs which have implications of closer concern to (secondary) science educators.

Solar Stills

Distilled water, conventionally prepared by an imported electric still, is needed for the preparation of solutions of chemicals (10). Electric stills do not appear to remain serviceable for very long, and a good deal of time and money elapses between the ordering of a new element and its arrival. Teachers are justifiably suspicious of the battery water to be obtained from motor car service stations.

Today, solar energy as a concept is a feature of recent science courses, and school solar stills provide opportunities for discussion of scientific, technological and environmental principles. These considerations have received attention in the Commonwealth Caribbean.

The Chemistry Department of the University of the West Indies at St Augustine has for many years met all its distilled water requirements from a bank of solar stills designed and built by a staff member, Oliver Headley (11). Headley's stills are also being installed in Trinidad schools, where they not only provide an adequate supply of distilled water (several gallons a day) but also provide a good example of principles of energy conversion, thermal physics, an 'alternative energy' source and local technology. Some stills have been in continuous operation since 1970 (Headley, 1979). One school's stills are shown in Figure 1.

A solar still has also been designed in Guyana by Sankies (1978), who provides data on its performance and suggests its possibilities both for schools and as a means of providing fresh water for the interior of Guyana. The Ministry of Education has installed a few experimental versions in schools and is exploring the idea of large scale production. A detailed scale drawing of this still is available; enquiries may be directed to the Commonwealth Secretariat Education Division.

No functional solar stills are known elsewhere in the Caribbean. A Barbados firm is manufacturing solar water heaters. And the St Lucia Association of Science Teachers (SLAST), at its first science exhibition, displayed an impressive collection of models which depended on alternative energy sources, including solar stills and ovens (3).

Biogas Generators

Compared with countries of the Far East (India, Thailand and China, for example), investigations into the production of biogas in the Caribbean are still on a small scale. As a teaching resource, the possibilities of a school biogas generator seem almost endless. Attitudes towards 'alternative energy' and the environment can be fostered; the chemistry and microbiology of the generation of gas from domestic and farm waste, and the physics and technology of its collection, distribution, and use, can be investigaged; agricultural considerations, for instance the comparative value of manure before and after it has been through the generator, are of interest; and the hazards and strategies of overcoming them, are concerns often neglected in science courses. As a resource for the development of problem-solving ability, central to the study of science, the installation of a school biogas generator is an exciting prospect. (It is not, however, a matter to be left entirely to the amateur; the hazards can be serious.)

Recognising the potential contribution of a school biogas plant to the study of integrated science, the Caribbean Examinations Council has distributed a design to its pilot schools, although as yet no schools appear to have built any (12).

The Scientific Research Council of Jamaica is also exploring biogas generation, and has helped a teacher (13) to build one for his home. This unit also acts as the home septic tank, and is enriched by manure from the teacher's chickens, ducks, geese and pigs. It provides him with virtually all the cooking gas he needs and could supply lights and a refrigerator. Only a few yards from the house, the plant is inoffensive and the teacher has shown great ingenuity in refining the design.

A project of this kind is likely to receive enthusiastic support from Government ministries and other public agencies, not least because it should save money.

Power Packs

All school laboratories, especially those for physics, need plentiful sources of electricity at low voltage. Distribution through bench terminals from a central fixture is not nowadays recommended; it is difficult to supply different voltages to different benches; terminal voltage is subject to variation as students switch their circuits on and off; children have a tendency to fiddle with and damage any kind of bench fixture; and if the central unit is a bank of accumulators, it needs skilled maintenance from the technician or teacher.

The most common alternative is dry cells. Their advantages are that they are readily purchased locally; they are so familiar that young children easily understand how to use them; there is no danger to children and comparatively little danger to apparatus. Disadvantages are that current available from them is so low that certain experiments are impossible; they need auxiliary cell holders which are sometimes a little complicated to set up; the cells and cell holders tend to 'disappear'; and, most serious of all, their useful life is so short that no school anywhere is likely to be able to afford to keep a good supply. At current 1980 prices, it would cost approximately US $20 in a particular country to equip a class with (locally manufactured) dry cells on the Nuffield scale for two or three lessons. This figure could represent half the entire annual fund available for science teaching in a school in one of the less affluent countries. The consequence is that not enough children have the opportunity to get their hands on enough electrical circuits. Dry cells are probably essential for the first few experiences in the study of electricity; after that, teachers agree, a more permanent power supply should be provided.

The next most common source of power is accumulators. The lead-acid accumulator has few, if any, of the disadvantages of the dry cell. However, its maintenance demands skill in physics which few teachers and laboratory assistants have, and its useful life is likely in practice to be limited to a few weeks. Discarded car batteries can, however, be a useful auxiliary source, since they can usually be obtained free from pupils themselves. The NiFe (alkaline) accumulator is much more difficult to damage from misuse or neglect, and it can be a most useful resource. However, for high voltages a large bank of accumulators is needed, and the current available is too small for some purposes, since the internal resistance is fairly high. None of the cells mentioned above can, of course, provide alternating current.

It is easy to see, then, why the Report of the 1977 Guyana Production TVC (p.12) states that power supply units are essential for laboratories. They are not cheap but, if carefully designed, should last for years and be usable by the average science teacher and his pupils Once the money is available, the main problem with power packs is that the variety in the catalogues is too complex to make choice easy for anyone but the very experienced physics teacher. A survey of 48 physics teachers in three Caribbean countries showed that only 10% considered that they had enough low voltage power units for their needs; another 12% of the A Level teachers and 16% of the O Level teachers were seriously handicapped by having too few; and the rest had none at all. More disturbing, 19% of the A Level teachers and 22% of the O Level teachers would not use these units even if they had them! The message for teacher education is clear. Teachers cannot even rely on others to choose for them and some teachers have been given certain equipment by their Ministry of Education but not the power supply essential for its use. Local production, preceded by extremely careful design and accompanied by user advice, would appear to meet a great need.

Recognising this in 1972, a lecturer in the Physics Department of UWI Mona (14) explored the possibility of production by students and technical staff of the Department. He designed and costed the most useful type; input 110 V AC, output 0-12 V AC or DC at 8 A. The project was abandoned when he found that, even given free labour and duty free components, the packs would be more expensive to assemble locally than to buy from abroad. (But he was doubtful about the adequacy of the switches being used by overseas manufacturers). Since 1972, foreign exchange problems for some Caribbean countries have added a new dimension to cost considerations, so that it may be worthwhile to pay more for local manufacture as long as the materials are also local. This would not be the case for items built from electrical components, which are always imported. Nevertheless, labour costs in Britain and elsewhere may have increased enough to warrant reconsideration of the project. Anyway, assembled power packs are not being imported, even if they are cheaper, and the teachers' need for local help may over-ride the cost aspect.

A similar need has been recognised by the Science Teachers' Association of Guyana (STAG), which saw the possibility of an input from the Faculty of Technology. The Faculty provides a technicians' course in which an assignment is the production of a 9 V DC power supply unit. Objectives, notes on components and construction details are provided in a workbook which itself should interest some science teachers (15). Intended to supply a transistor radio or calculator, the output of the unit is only 50 mA, quite inadequate for school science (and therefore unlikely to survive a single teaching period in the hands of most teachers). However, the Faculty technical staff have designed and built other power packs to meet specifications for individual experiments, and they see no reason why they could not meet design and large-scale production demands from schools. What is now needed is a formal request from STAG through the Ministry of Education, assuring the technicians of adequate compensation for their time and expertise. A preliminary needs assessment of the kind reported above would be useful.

The design team for local production must include a teacher knowledgeable about the uses and abuses to which power supplies are put in schools. There must be very careful protection against overload, not by using a convenient cut-out which can be instantly reset, but by a more clumsy fuse (which, nevertheless, should be readily available locally). Once a teacher has gone to a little trouble to replace a few fuses, he will come to understand the ways in which power packs are commonly abused. There should also be strategies to protect the secondary equipment from an excessive voltage - a device on some kinds of overseas power packs is a voltage setting operated by an Allen key, simple for the teacher who has the key in his possession, difficult for all but the most mischievous and determined of pupils. The mains outlets in schools are often without a third (earth) connection. Mains-operated equipment requires special attention to the safety of the child and all members of the design team must ensure that this consideration is paramount. Bench testing under the most rigorous conditions should precede distribution to schools.

Regional manufacture would have to take account of the different characteristics of mains supply. Some teachers, but not all, are aware that they must specify input voltage. In some countries of the region, the national supply is at 110-120 V, in others it is at 220-240 V. And the school supply, or parts of it, may be different from the national standard, and not always explicit to users of the outlets. Also, there is no regional common frequency - we find 60 Hz in some countries, 50 Hz in others. Although power packs are not sensitive to mains frequency difference, other apparatus such as ticker-timers and signal generators will not function properly on the wrong frequency, and suppliers and consumers must be aware of options.

A considerable proportion of the cost of imported equipment is the research and development cost; local producers must be prepared to substitute their own research and development, and the low tension power supply is a good illustration of the importance of this.

Electronics Teaching Kit

Final year physics students at the University of the West Indies are required to undertake a project, which may be a teaching project. As an example only one student has chosen the design and construction of a school equipment kit. This is a set of modules for the teaching of electronics, the modular approach being chosen because it provides flexibility and is easier to understand. The kit contains :

1. A basic unit, an unbiased transistor amplifier with three inputs and two outputs.

2. An indicator unit, which is essentially a digital voltmeter.

3. A multivibrator unit.

4. An AND gate unit.

5. A JK flip flop unit.

6. A square wave generator.

7. A tuned circuit.

8. A detector unit.

9. A filter unit.

All modules except the tuned circuit are of identical dimensions. Leads with banana plugs are provided to link the modules, and a simple aerial is provided. A booklet describes the construction and suggests ways in which the kit can be used to explore the applications of electronics (16).

Because school physics and integrated science courses do not yet include much in the way of electronics, kits have not yet been put into production. Even at present, however, there are electronics courses in the technical wings of the senior comprehensive schools of

Trinidad and Tobago, and, although these wings are very well equipped, it could be a useful exercise for the children to build their own kits from this or similar designs. It would also provide an appealing project for a science club or an individual student, who could do much of the work at home.

Models of Applications of Physics

Physical science courses in schools are especially open to the charge from students that they are 'not relevant'. To help children realise that physics contributes much to engineering and medical technology and the quality of life, the Physics Department at UWI Mona has set up a Mini-Physics Museum with the aid of a grant from the Organisation of American States. The models in the museum, built by staff of the Department, are available for schools to borrow for events such as an Open Day (17). The list of models so far produced is as follows :

1. Model of retinal processing, which takes up where elementary textbooks leave off. The 'retina' is an array of 156 phototransistors and can be used to demonstrate image perception, colour vision and its deficiencies, and relative distribution of rods and cones in the retina. The display is a box containing flashlight bulbs and a viewing screen.

2. Heart monitor (electrocardiogram) connects points on the surface of the body through an amplifier to a cathode ray oscilloscope.

3. Coupled oscillation and resonance. Two sets of pendulums are driven by a stream of air from an electric blower in order to demonstrate the principle of resonance common in everyday life.

4. Electronic organ, consisting of an oscillator, amplifier and speaker.

5. Windmill generator which depends on the principles of Bernoulli and electrical generation to pump water and to generate electricity for immediate use or storage.

6. Magnetic suspension which depends on a transducer whose voltage output is proportional to the light incident on it, and this is dependent on the position of a suspended ball. The principle is used in frictionless bearings and magnetically suspended trains.

7. Tesla coil, put into the context of the magic of physics since it can produce 'such fascinating effects'.

A handbook for users is available.

This enterprise will make little contribution to solution of the day-to-day classroom problems of the teacher. However, supplemented by a discussion of the physical principles, it can do much to show A Level physics students how their classroom physics can be put to work and can encourage them to engage in design, construction and investigation themselves. Even at a lower level, there are motivational opportunities. For example, two D stream fourth formers, potential drop-outs, encountered the Tesla coil in a book on physics models in a science club and, as a consequence, went on to take physics PhDs. For a team of 16 university physicists to engage in a project to make physics exciting for school children is an action that can only be beneficial to both the university and the schools, and one that is unfortunately too rare.

Local Manufacture

The foregoing description of prototypes, models and design which could lend themselves to large-scale production for schools is a short one. Clearly, curriculum development in the Caribbean has not been accompanied by the development of equipment for the curriculum, such as was undertaken for PSSC, the early Nuffield projects and Kenya's SSP. One reason for this is that the largest country in the Commonwealth Caribbean has a population of only some two million, while the combined population of the 16 other West Indian countries from Bermuda and the Bahamas in the north to Guyana in the south is less than three million, only a small proportion of who are of secondary school age. Bhattacharyya, of India's NCERT, listing basic equipment for a low cost science equipment production centre in his presentation at the Bahamas Workshop (Commonwealth Secretariat, 1977, pp.37-40), mentioned an average production worth £100,000, and observed that the list might prove uneconomical for small countries. As a solution he suggested a common regional centre. Although this idea has merit, it is difficult to identify any existing regional organisation which could be expected to initiate such a centre.

For primary science, however, national or regional mass-production is a possibility for the future. As has been said earlier, primary science makes smaller demands on research and development; the numbers of children are larger; primary science curriculum development has assumed an importance that it did not have in the 1970s; and a regional UWI/USAID project for primary schools has come into being.

In discussing local design and production, we should not confine ourselves to financial issues, as the foregoing account should show. A financial investment may or may not lead to financial profit; we can be sure, however, that the educational gains would be valuable and the human creative ability in the region would be recognised and used.

It is unlikely that the Caribbean will ever produce even most of the science equipment used in schools as has been achieved in Turkey, where DAYM produces over 80% of the equipment required for teaching physics (Commonwealth Secretariat, 1977, pp.77-80). It is probable that local design will lead to mass production of some items and accordingly provide better learning of science and an outlet for the talent in the region. There has so far been no co-ordinated appraoch to this.

However, there is the possibility that the Caribbean Development Bank might be interested in the local fabrication of science apparatus for use in primary and secondary schools, given the following evidence:

1. There is an economically significant demand for science apparatus which can be fabricated locally or within the region.

2. There exist prototypes or models for apparatus which can be developed for local fabrication through appropriately designed studies which may involve activities such as:

(a) Adaptation to local materials, local requirements or local skills.

(b) Design and testing of a suitable small scale plant for fabricating scientific apparatus.

(c) A feasibility study.

3. Governments and science teachers' associations will give strong support to the project and will participate in the development of a system to programme production, supply raw materials and deliver finished products in a way that is well suited both to the needs of schools and to the operating limitations of the production plant.

It is hoped that the Bank, a finance organisation, could commission studies to establish such evidence, and a project of this kind could benefit from the experience of the Commonwealth Secretariat, NCERT, RECSAM, DAYM, SEPU of Kenya and others. The Bahamas and Guyana Workshops could well prove important first steps towards the solution of some regional needs.