LOW-COST SCIENCE TEACHING EQUIPMENT: STRATEGIES FOR USE

W.J.E. Indge
Formerly Education Consultant, School Equipment Production Unit, Nairobi, Kenya

The discussion of lead papers presented at the first of this series of Commonwealth Regional Seminars on Low-Cost Science teaching equipment held in the Caribbean in November 1976 revealed that there was considerable confusion over the term "low-cost". In an attempt to avoid a similar problem arising here, it might be worth-while to try to define this term at the outset. "Low-Cost" 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 improvization 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.

Presumably for the sake of convenience, the lead papers of this seminar have been devised to focus separately on production and use. This approach, however, reflects a distinction which has led much too frequently to two serious shortcomings; the technician loses sight of educational objectives and the curriculum specialist demands a particular item of apparatus without giving adequate thought to its production. The Caribbean seminar/workshop already referred to, provided an excellent example of this. As might be expected with a group of experienced educators, good ideas abounded; failures resulted mainly from a lack of understanding of the properties and limitations of basic materials. It follows then, that while this paper specifically deals with the use of low-cost equipment, a central theme must be the underlying co-operation of the educator and the technician.

Traditionally, textbook production has been seen as central to all aspects of progress in science education. The design and production of the accompanying apparatus though, is regarded as having a commercial bias. As such, it tends to be a long way down the list of government priorities, and meets with little academic support. Under such circumstances, it is scarcely surprising that many projects in equipment development and production are struggling on very limited budgets. They are staffed by a dedicated few who have little contact with key personnel in schools. Any strategy for the use of low-cost science teaching equipment must begin by determining the exact needs of the particular system, its teachers and its students.

The Needs of the System

The variety of cultural and political backgrounds at this Meeting is such that it is difficult to generalize. I shall therefore draw extensively on experience gained while working with the School Equipment Production Unit (SEPU) in Nairobi in the hope that specific points will emerge which bear some resemblance with the situation in other countries.

The principal objective of SEPU has been to produce a basic but adequate range of apparatus to enable students to carry out experimental work up to the level of the East African Certificate of Education. In order to achieve this, it has been necessary to look much further than the guidelines provided by the examination syllabus. Some of the points considered were:

Educational Problems. The use of a practical, inquiry-based approach is seen by almost all science curriculum specialists as desirable and consequently it has a prominent place in modern science syllabuses. However, we must recognize that the task of interpreting the curriculum belongs to the teacher. Teachers are aware that techniques that involve student practical work are recognized as good practice and, not unnaturally, they are reluctant to admit to failure to use such methods. Although much pre-service training is centred on these techniques, teachers are reluctant to depart from patterns they were familiar with as students. Often, once teaching practice is over, there is a rapid reversion to what is referred to as traditional teaching (i.e. a series of lectures relieved by occasional demonstration exercises).

Thus merely providing schools with the necessary apparatus is no guarantee that it will be used. This fact was confirmed in a survey recently conducted by a leading equipment production centre. Results revealed that 43% of the kits had been in the school for six months and had not even been unpacked! Surely, it cannot be overemphasized that production units should not expect teachers to use new and different apparatus without considerable guidance, a corollary being that such centres need to have an effective feed-back system to guide them.

Financial Constraints. It is pointless in a paper of this sort to discuss current economic problems and attempt to relate them to education; it is quite sufficient to state that the situation in most schools in Africa leaves much to be desired. Clearly, financial issues should feature prominently at the planning stage of any project involving the production of school science apparatus. No apology is needed to repeat what was discussed in the opening paragraphs; the prime economic consideration should not be the savings that can be made over commercially available items but rather whether the new materials relevant to the local situation will fall within the budget of schools. Frequently this calls for radical thinking by curriculum planners.

An example for SEPU is relevant here. In the original biology kit it was proposed to include an inexpensive student microscope. By purchasing in bulk direct from the suppliers the costs could be cut down enormously. However, it was quickly recognized that the item would still fall well outside the science vote of many schools. Thus after a careful consideration of biological and educational aims and objectives, a substitute was devised; a stand-mounted slide viewer and a set of photographic slides. Not a microscope certainly, but a very good substitute and, more to the point, teachers could afford to purchase a class set at less than the cost of a single imported microscope.

It must also be borne in mind that the same financial constraints will not apply to all schools in a given system. Primary schools in general have so little money that were SEPU, for example, to embark on producing materials for them it would be disastrous to think in terms of the present kits, successful though they may have been at the secondary level. It was pointed out at a workshop held in Botswana in 1975 that "Primary school science is not secondary school science made easier". Its objectives are different. It might be regarded as more of a way of teaching the methods of science, by training children to observe, collect evidence by simple investigation, and communicate their results to each other. As the exact nature of the factual material is of less importance, it is possible to make a fuller use of the child's immediate environment. This is the approach of the Science Education Programme for Africa (SEPA) and as a result the course has almost become no-cost, let alone low-cost in terms of apparatus.

Multi-Level, Multi-Purpose: The Kit Approach. Whatever size a production unit for low-cost materials may be, two basic strategies are open to it: bulk purchase of either locally made or imported material, and local production. The particular emphasis is determined by such economic factors as cost of raw materials and of labour. These same factors will also determine to a large extent the minimum cost of the individual items that can be produced by the Unit. In order to make further significant savings, it is necessary to look towards the strategy for use. It may be relevant to consider two questions in this context.

1. In theory, it should be possible to design a range of apparatus which can be used for different purposes at primary, lower secondary and upper secondary levels. How realistic is an approach of this sort? Although such a move might be expected to improve cost effectiveness, it is frequently unacceptable in practice. Teachers are reluctant to entrust heavy-handed junior students with apparatus reserved for older students. Frequently, difficulties exist in free movement of apparatus and materials between departments and between educational levels within one institution. The chance of apparatus exchange between schools is almost non-existent.

An extension of this idea is a loan system operating from a central pool. A basic range of frequently used items of apparatus stored in the particular school can be supplemented by additional items when the need arises. Though this idea has proved successful in the teaching of the integrated science course run in the junior secondary schools in the Seychelles, in almost all other countries within the region represented here the cost of organizing and running a central pool for equipment would be prohibitive.

2. Science kits contain a very limited range of items, but each item may be used in a considerable number of teaching situations. Are there any drawbacks to this type of multipurpose design?

The answer depends very much on the production unit concerned. The weakest link in the kit approach is the replacement of lost or damaged items. There are a number of possible solutions. SEPU for example prefers replacement to repair, since the cost of individual items is low.

On the other hand, Turkey's School Materials Manufacturing Centre, considering the emphasis it places on mobile workshops and the in-service training for teachers which includes instruction in repair, appears to favour repairs. What matters is that provided some form of satisfactory service for the replacement of standardized parts can be maintained, the kit system can represent an enormous saving.

Individual Students Experimentation/Teacher Demonstration. Practical work in schools is often divided more or less rigidly into two categories, individual experiments and teacher demonstration. Current curriculum development favours work on an individual basis, and much effort is being made to persuade teachers to move away from the traditional demonstration. We must not forget that in many developing countries we are considering a group of very inexperienced teachers, a high proportion of whom may be untrained and may, for want of confidence and security, prefer the comparatively more controlled and predictable demonstration exercise.

Quite apart from educational considerations it is necessary to look at a purely business factor. For local manufacture on a commercial scale to be economically viable there must be a sizeable market. Let us consider India as an example. Middle schools alone number over 100,000. Because of this large market, the National Council of Educational Research and Training (NCERT), which is responsible for the necessary development work, has no problems as far as size of target population is concerned. In fact, the target population is so large that NCERT is able to afford to offer two categories of kit, one for teacher demonstration and the other for individual student experimentation. In the case of a country like Kenya, however, there are only about 1250 secondary schools, and there are many items of equipment that SEPU cannot manufacture because the production run is not sufficiently large. This applies obviously to the development of a demonstration kit. SEPU is therefore concerned mainly with the production of individually based science kits. This fits in well with educational objectives, for one of the practical aims of the SEPU kits has been to encourage an investigatory approach which will improve both the general standard of science teaching and the interest displayed by students.

We are nevertheless presented with a dilemma: on the one hand it is educationally desirable to move towards student experimentation; on the other there are constraints imposed by meagre school budgets and a lack of adequate numbers of qualified and experienced science teachers.

This dilemma is of fundamental concern when one is considering strategies for the production and use of teaching equipment. Perhaps the best solution is to produce teachers' manuals to accompany the use of apparatus which provide adequate instructions both for work in small groups and for teacher demonstration exercises. Some of the factors one must bear in mind in designing these manuals are the academic qualifications, professional training, experience, and motivation of the teachers.

The Circus Approach. Although frequently advocated as a strategy for more economical use of limited science equipment, the "station" or "circus" approach has severe limitations. The inexperienced teacher is reluctant to make full use of practical work. In the little that he attempts, he requires experimentation to be rigidly controlled. Indeed, a situation in which small groups are working on different investigations is much more difficult to handle successfully and effectively. There might be a saving on cost, but the time and effort needed to arrange a single lesson of this sort are considerable. Additionally, a circus technique will come into conflict with the science kit approach; multi-purpose use of individual items will obviously limit the number of experiments that can be conducted at the same time.

The Needs of the Teacher

The report of the 1975 Commonwealth Conference on "Materials for Learning and Teaching" made the following recommendation: "Educational authorities should ensure that teachers receive as an integral part of pre-service and in-service training, whatever instruction they need to enable them to take full advantage of the equipment and materials that may be available to assist them in their work." This statement confirms the sentiments of many production units. The need to see teacher training as a necessary component in the process of introducing any new range of low-cost apparatus cannot be overemphasized. A review of the work of a number of successful units would provide a catalogue of examples, but here we will consider two only:

In South East Asia, The Regional Centre of Education in Science and Mathematics (RECSAM), organizes courses relating specifically to equipment. In its own words, RECSAM describes these courses:

> "To assist each member country build up a core of equipment, key personnel who could develop prototype equipment and produce design plans for dissemination as well as organize in-service training of teachers and laboratory personnel in equipment production, RECSAM has successfully implemented the course, "Development of Primary Science Apparatus". This intensive course of about ten week's duration is specially designed for SEAMEO key personnel who are actively involved in equipment design, development and manufacture in their respective countries."

Here the emphasis is on the training of a selected few at a production level. What of provision of in-service training at the local level for teachers? This is exemplified by our second example, SEPU.

Of the approximately 1250 secondary schools in Kenya, some 850 are either private or are built on a self-help basis to serve a local community. Figures published by the Ministry of Education show that all secondary schools are staffed largely by non-graduate science staff. Although many of them are enthusiastic and very able teachers, a high proportion do experience problems of an academic nature at the form 4 (East African Certificate of Education) level. In the non-government sector, the teacher shortage can be described as acute. Vacancies tend to be filled, therefore, on a temporary basis by secondary school leavers. Every opportunity must be taken to raise the academic standards of these teachers without, at the same time, damaging the little confidence that they possess.

There is the problem which arises from the relative inexperience of science teachers. With the shortage of trained science graduates, promotion to non-teaching posts of responsibility is rapid. As a result, it is unusual to find experienced African science graduates as heads of science departments. Inexperience frequently results in lack of confidence.

Poor motivation of teachers is something that must be accepted. A significant proportion of teachers lack the necessary commitment to their profession, and this needs to be recognized so that adequate plans can be made to overcome it.

Based on the awareness of the problems described above, a series of courses were planned to promote an interest in science kits and to encourage their correct use. For the benefit of participants from the non-government sector particularly, the courses were designed to include some basic educational theory and classroom technique.

The basic plan was to provide a series of one-day courses throughout the provinces, each involving as much teacher activity as possible. The courses were designed on a unit plan, combining a local adaptation of some of the material developed in the UK Science Teacher Education Project with opportunities to use the SEPU science kits. In outline the most successful combination of units was:

(a) Introductory session - aims and methods in science teaching. A group discussion led to the establishment of a set of aims for the teaching of science. These were used as a basis for comparing specially prepared slide-tape sequences of two methods of teaching - a lecture and an inquiry-based lesson. Discussion of this confirmed the view that limited apparatus made the preferred inquiry approach difficult to implement. This paved the way for introduction of the science kits themselves.

(b) Examination of the kit material - A circus of experiments and corresponding worksheets was set up and teachers carried them out. It was argued that only by putting themselves in the place of students could they appreciate the difficulties that were likely to be encountered, and judge the suitability of the material for the classroom.

(c) Closing session - Discussion centred on the problems of being a student. A purposefully light-hearted approach was made here and a circus of gimmicks and games was laid out to highlight some of the problems likely to arise in a practical class.

It is, of course, ridiculous to pretend that such a course would be ideal in all circumstances. What matters is that it worked in the Kenyan situation. Nevertheless, there are two general points that are worth stressing if the most effective use is to be made of the time available for a one-day course:

(a) A unit plan has considerable advantages in that it produces variety for the participants and can be altered easily if the need arises.

(b) One of the most difficult problems associated with the one-day course is establishing a relationship with the participants. The dominant part of teacher involvement makes this much easier and allows for better communication between all participants.

The diagram (page 35) illustrates the training available to an individual teacher. He can attend an introductory course at which he will be able to examine and use some of the science kits and familiarize himself with relevant teaching methods. Follow-up courses held later will enable him to go into greater depth in some of the experimental work as well as provide him with practice in other teaching skills. Finally, if he is still interested, he may have the opportunity to continue to gain experience and help through half-day practical sessions which are organized locally.

Part of SEPU's long-term plan was to identify and train the necessary personnel to conduct similar courses at a later date and to follow up the introductory programme. Since follow-up work to a course of this nature is absolutely essential, SEPU has started to make use of provincial organizations in this aspect of its work. With finances very limited, this has centred on existing local organization, and help has been received from the Ministry of Education's local provincial inspectors, the British Council and, what is potentially a very valuable link, the Kenya Science Teachers' Association. SEPU provides assistance by way of personnel and equipment.

Unless attendance during in-service courses is made compulsory (and this is, as far as I know, not the policy in most Commonwealth African countries), it is impossible to reach every teacher in this way. Alternative strategies are necessary. Most important of these is an adequate teacher's guide. The SEPU biology guide for instance, sets out to meet the same objectives as the courses. It is in two sections: a short introduction which puts in simple language some advice on teaching method, and a main part which discusses each investigation in turn. Throughout the booklet, a compromise has been struck between providing full information and keeping the guide brief enough to appeal to readers.

Any programme of in-service training is expensive. A brief examination of the SEPU programme in terms of cost-effectiveness may be of interest here. The largest single item on the budget is the transport and accommodation of teachers, particularly where co-ordination between schools is not possible. This was kept to a minimum by repeating courses on a provincial basis. The cost of each teacher's transport and subsistence was met by his school from the appropriate vote; SEPU paid for staff accommodation and transport. A full list of participants was made and from this the total of orders which could be directly attributed to these courses calculated. These figures are shown below:

Total number of courses - 6

Total number of participants - 170

Expenses of course tutor (transport and subsistence) K. Shs 2650

Sales for March 1976 directly attributable to courses - K. Shs 41,899

Pre-Service Training

There is little to add here to the ideas presented in the preceding section. Any institution involved in teacher training has a responsibility to its students to assist them to gain the most from such apparatus as is likely to be found in its target schools. If the majority of students are to be posted to rural schools with limited facilities, this must be reflected in the training. SEPU has produced a pre-service scheme along the same lines as the successful in-service teacher training programme. These units are at present used as an integral part of the appropriate teaching methods courses at the Kenya Science Teachers College. Possibilities exist as well for follow-up during students, final teaching practice but, at present, a shortage of personnel precludes this.

The Needs of the Student

A student's needs must also be considered in designing satisfactory low-cost equipment. Identifying these needs is not easy. Thus, teachers report problems (e.g. of slowness, language, and vocabulary) that do not feature frequently in students' comments. Part of a survey of science kits in Kenya involved inviting a sample of over 200 form one students to write a sentence in answer to the question, "What do you find hardest about science lessons?" This is not the place for a detailed analysis of the results but the following remarks are relevant to our discussion of strategies for use of low-cost teaching equipment:

(a) Over half the test population listed difficulties with the mathematical part of science, particularly physics. One's heart goes out to the student who wrote, "Physics is a hard and unmemorable subject to myself. If the calculations in physics were not there, I could be one among those brilliant physics pupils".

(b) A large number of students experienced difficulty with the setting up and handling of apparatus. Problems listed here range from "When I am holding a beaker I do tremble very much and fear", to more general difficulties in assembly. It was disturbing to watch a group of form one girls in a rural secondary school attempting to assemble a nut and screw.

(c) Failure to understand rather than difficulties in drawing accounted for most of the responses associated with diagrams. To many students, diagrams represent an entirely novel means of communication.

(d) Also frequently listed was the failure to understand why a particular experiment was being carried out. Students need to know this.

A paper such as this obviously cannot present a universal panacea. Solutions for the effective use of low-cost materials must be individually tailored to meet the needs of the system, its teachers and its students. To determine these needs, incorporate them into each stage of design and production, and provide for the successful introduction of the resulting material into school, needs the full co-operation of teacher, educator and technician alike. A strategy for production must go hand in hand with a strategy for use.

REFERENCES

1. Commonwealth Secretariat, Low-Cost Science Teaching Equipment: Report of a Commonwealth Regional Seminar/Workshop, Bahamas, 1976.

2. Commonwealth Secretariat, Materials for Learning and Teaching: Report of the Commonwealth Conference, New Zealand, 1975.

3. Commonwealth Secretariat, The Production of School Science Equipment, 1975.

4. Ferreyra R.E., Low-Cost Equipment for Integrated Science Teaching, Latin American Seminar on Integrated Science Teaching, Uruguay, 1975.

5. Report of the Primary School Science Workshop, Lobatse Teacher Training College, Botswana, 1975.

6. Government of Kenya. Ministry of Education Annual Report, 1973.

SUMMARY OF SEPU IN-SERVICE TRAINING SCHEME