LOW-COST SCIENCE TEACHING EQUIPMENT: TRAINING FOR USE

Hubert M. Dyasi, Programme Director,
Science Education Programme for Africa

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 knoweledge 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 canno 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 seience 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 elimiate 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 ih the use of the balance, one must know the <u>meaning</u> 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 <u>experience</u> 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 tge 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 familiarizatin 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 essense 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 juse 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 date 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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