# PRACTICAL SCIENCE IN

# LOW-INCOME COUNTRIES

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**INTRODUCTION**

Practical work plays a central and important part in the science programmes of schools in many countries. It often assumes the dominant and dominating role involving teachers in a vast amount of time, effort and expense. Most of the developing and low-income countries have many difficulties in furnishing the laboratory facilities and environment for teaching practical science.

In this unit, some important aspects regarding practical science in low-income countries have been described. These aspects include context and aims, present practice, barriers to change, appropriate response, providing the resources to these countries and choices.

**OBJECTIVES**

After reading this unit, it is hoped that you will be able to:

1. Know the context and aims of practical science
2. Know the situation and practical science in low-income countries
3. Described the barriers to change the present practices
4. Identify the resources required to improve the practical science in low-income countries

**PRACTICAL SCIENCE IN LOW-INCOME COUNTRIES**

Although defining the countries to which this chapter refers is not straightforward, they do have a number of factors in common: low per capita income; predominantly rural populations; economic based on primary products; relatively recent experience of political independence; and limited access to schooling, particularly at the secondary level. While they are situated on several continents, the majority of examples in this chapter are taken from sub-Saharan Africa, the region which has the greatest difficulties in providing the normal facilities of trained teachers, laboratories and equipment for teaching practical science.

**Terry Alsop**

If science is to be learned effectively, it must be experienced. **(UNESCO 1973)**

The laboratory is a unique facet of science education. **(Tamir 1989a)**

**4.1 Context and Aims**

By the process of importing ‘packaged’ curricula, recipient countries unwittingly submit themselves to a particular view of the world…There is an unspoken assumption that the image of science described by the imported curriculum is correct, and also that it is suitable for all pupils (Ingle and Turner 1981).

The world-wide period of centralized curriculum development which began in the 1960s has not left these countries untouched, typically, as in sub-Saharan Africa; it coincided with the granting of independence from a colonial power, but not with freedom from influence of the metropolitan countries. The models of science curricula may vary considerably, but the counting pattern of dependency on curriculum experts, on textbook publishers, on science equipment manufacturers, and on experimentation conceived thousands of miles away remains hauntingly similar. The examples are legion, even stretching to the influence of the science curricula of the Soviet Union on Chinese schools and universities in the 1950s. Perhaps the most notable feature of the curriculum development movements in science was the insistence on the importance of student experience of the science laboratory, usually through some form of teacher-directed investigational process. In the northern industrialized countries questions have only recently emerged as to whether this approach provides the most interesting or the most successful means providing secondary school students with a liberal scientific education (Jenkins 1989). Examples of this form of cultural imperialism abound. For example, the Nuffield science projects of the 1960s, with their emphasis on student experimentation in the style of guided investigations, were taken up and modified for use in East Africa and Malaysia, in the former being grafted onto a tiny secondary school system still largely staffed by expatriates and resources by imported equipment. In each case the later attempts to generalize this approach to an expanding secondary school population faltered, leading to headlines in the press such as “Revert to pure Science, Education Ministry urged” (New Straits Times 5 June 1978). The way in which the Scottish Integrated Science course was adopted in only slightly modified form by a substantial number of countries, aided by the activity of commercial publishers, has been documented by Williams (1979). In taking on a tightly structured and well-tested course for junior secondary use, they were also buying a particular approach to practical science. Sim (1977) has reported that the inquiry approach espoused is at variance with the cultural values of many teachers and parents.

A pause for reflection on the aims of practical science which accompanied these curriculum projects may be appropriate here. In the context of northern industrialized countries, the most prevalent aims can be grouped under four headings: stimulating interest and enjoyment; learning experimental skills and techniques; teaching the processes of science; and supporting theoretical leaning (Woolnough and Allsop, 1985). In espousing these aims, if only at second hand, countries took on commitments to the provision of resources at a level often beyond their realistic capacity to deliver, and most important, the necessity of providing appropriate assessment instruments. Typical of such a commitment would be that made in the Zambia Education Reform Document (1977). Pupils should be able to master useful practical skills which they would apply in life in various ways. They should adopt a scientific attitude and approach, they should observe, collect information, draw conclusions and apply what they know/Present practice.

What, then, may we expect to see of practical science in action? A trite answer would be with honorable expectations, very little! But usually with plenty of extenuating circumstances. It may be of help to consider in turn three generally recognizable stages: primary, junior secondary and senior secondary schools.

Science teaching in primary schools has, until recently, rather oddly, had a higher profile in the national curricula of many low-income countries than in those of the industrialized countries. This is presumably explicable in terms of realistic expectations that many children will only receive primary schooling and therefore only have this opportunity to be acquainted with science learning. Many primary science curricula have been developed in Curriculum Development Centers which appear to have the right emphases. For example, strongly community and environmentally oriented approaches, as in the splendidly conceived rural development projects of Namutamba (Uganda) and Bunumbu (Sierra Leone). The needs of teachers in initial and in-service training appear to be well served by Young’s important book, Teaching Primary Science (1979). Practical science has been encouraged by the supply of kits of equipment to schools, and linked practical workbooks (for example, in Pakistan). Yet in thousands of rural primary schools, practical science simply does not happen. Why not? At least-three crucial factors need comment.

First, very large classes, often with 60 or more pupils working in very cramped conditions, set organizational challenges in relation to the delivery of practical science which would deter most teachers. They parallel the difficulties of organizing meaningful practical agricultural activities for large numbers of primary pupils.

Second, most primary teachers have a personally limited background in practical science and only slight confidence in teaching methods other than exposition; In many low-income countries primary teachers of necessity take additional employment to supplement meager salaries. In consequence, they have little spare energy to plan for complex practical activities.

Third, those who complete primary schooling will often have to face a fiercely competitive examination for entry to secondary school, perhaps with only one child in 10 or 20 succeeding. This examination will rarely test science knowledge and understanding and never practical skills in science.

At the other end of the school system, the senior secondary school, the typical picture is of a very highly selected group of pupils taking highly academic examinations in some cases still related to international examination networks, for example, the system of Advanced level examination. Here, students abilities in practical science may supposedly be tested through questions set in written papers (as in China), or through practical examinations set for all students (as in the practice of the West African Examinations Council). If the latter system is used, then a form of practical science has to take place in the schools, but in usually limited very closely to exercises which can be practiced in preparation for the examination. Class sizes are by now smaller and so managerial questions do not loom so large, but resources now constitute a serious problem. The type of science curriculum prescribed normally assumes laboratory experimental work at a high academic level, dependent on the provision of equipment, chemicals and services which is often simply beyond the resources of the country. In a recent survey of 50 Zambian secondary schools, Varghese (1988) found that only three had adequate facilities for practical science, and even bin these only demonstration experiments were performed by the teacher, equipment and chemicals being conserved for use in practical examinations. The three reasonably equipped schools were private foundations with alternative sources of funding not available to government schools. In the 1970s, splendid laboratories were built and equipped in many African countries with funding from the International Development Association (IDA), an affiliate of the World Bank. On a recent visit to Sierra Leone, the writer saw many of these in decay one laboratory was being used as poultry house, and in another all the chemicals and equipment were piled together in a heap in the preparation room while the laboratories were used as classrooms. A recent World Bank (1988) report concludes: “Quality education is just not possible in laboratories and workshops that have no electricity or water because wirings, fuses and plumbing have deteriorated and where equipment does not operate because spare pans and consumables are lacking.

In between, we find the political imperative to provide serious evidence of progress towards extension of access to secondary schooling at least for the junior secondary years, in response o the greatly increased numbers of pupils completing primary schooling. Again, science curriculum development has outstripped the provision of resources and trained teachers in many countries, particularly in respect of the predominantly rural schools which are traditionally under-resourced. One of the most innovative responses in the ZimSci course for Zimbabwe schools, where the quirk of delayed independence has allowed the developers to learn from others mistakes and to develop a realistic, practically based course built around kits of equipment and associated text material made available to all schools. Even this project, designed for rural, day secondary schools, has been forced by public pressure simply to deliver in less expensive packages the same traditional science syllabus of established, elitist schools (Knamiller 1984). We shall return later to this dilemma.

**Self Assessment Questions**

Q.1: What are contexts and aims of laboratory work in low income Countries?

Q.2: Why it is worth to compare the aims of practical work in low income countries?

**4.2 Barriers to Change**

It has already been hinted that the prevailing paradigm of inquiry oriented practical science may map uncomfortably onto the teaching and learning modes associated with instruction in the previously stable, pre-indusial societies of many low income countries. Wilson (1983) has pointed out that an instructional mode where teacher and learner roles are clearly defined and differentiated according to expectations brought by the child from the home environment dominates most science lessons in African and Asian countries. I would wish to argue that this scenario particularly affects teachers of science, whose own experience of science simply reinforces and validates the transmission mode and expository style (not a problem unique to low income countries). Lee (1982), writing of an Islamic culture concludes:

There are also exist social attitudes and cultural traits in Malaysia which may be antithetical to the spirit of Western science. One cultural trait is that not only is it not ri9ght for the young to question their elders but teachers also share the same conservative attitude and are used to being directed from above. It is doubtful that this attitude of acceptance of authority can be conducive to the development and discovery learning of science among pupils.

It seems to me that a more appropriate focus for our concern should be the ways in which science teachers are trained. At present typical science teacher educator in a sub-Saharan African country has received his/her own science an elite secondary and higher education system, presenting an academic rifled view of science which generates little of the openness of approach needed in guiding student teachers out of their own background. Frequently the same teacher educator has spent little or no time as a science teacher in primary secondary schooling the environment of college or university is demonstrably more attractive as a workplace. So the twin goals of developing an approach practical science which is both open and enquiring but which also relates it to realistic assignments of resources are very rarely seriously addressed, never mind attained. Somewhat bizarre mismatches may occur, as in Oman, where the linking of national educational aspirations with oil revenues has allowed the equipping of secondary schools with splendid laboratories. Unfortunately, the teaching force remains entirely expatriate, recruited chiefly from Egypt and Sudan, from educational traditions where practical science is rarely part of the school experience. So far the laboratories gather dust, waiting for a well trained first generation of Omani science teachers. Some encouragement can be gleaned from Koroma’s (1975) study of Sierra Leaneon science teachers, which showed that local teachers more likely to have positive attitudes to investigational approaches than expatriate teachers, many at that time coming from the industrialized.

A final, and in my view very significant, barrier to be surmounted is the addiction to summative practical examinations as part of science assessments at the final stages of senior secondary schooling, typical of the Advanced level equivalent examinations operating in most former British territories. They suffer from all the usual defects and limitations of nationally set practical examinations, exacerbated by the logistical difficulties for teachers in resourcing them, and again for teachers, the very real pressures of maintaining security. While guaranteeing the usual justification their continuance some degree of student practical science, they offer a very limited range of practical activity, with a very negative feedback effect on what occurs in earlier years in science. The continued existence of practical examinations precludes serious discussion and analysis of the purposes of practical science, but is staunchly defended by many indigenous science educators (the writer may be seen as an outsider here) who argue quite properly in terms of the rights of their secondary school students to have access to science education of an internationally recognized standard.

**Self Assessment Questions**

Q.1: Discuss the barriers to change related to laboratory work in developing countries?

Q.2: How will you overcome barriers in Change lab practices in Pakistan?

**4.3 Appropriate Responses**

The search should be on for models of practice which can lead to national or regional versions of science education which relate, as King (1986) suggests is happening in India, to local traditions, development plan and modernization strategies. Fully articulated models probably do not exist but some interesting experiments have come to light.

It is slightly strange conjunction which brings to the attention of educators in both low income and industrialized countries a concern for environmental, societal based approaches to science education at this time. In low income countries the argument is developed at least in part as a way of utilizing the natural environment as resources for practical science in the likely continuing absence of access to more formal laboratory science we should probably view this positively. Not that this scrutiny of the environment is a particularly novel idea. Cole (1975), developing a course for Sierra Leone, was able to show that traditional African culture, properly employed, holds a rich source of materials for developing the scientific method of inquiry and knowing about the various elements and processes in the African environment. More recently, Knamiller (1988) has, within a constructivist framework, systematically explored the potential of rural science and technology in Malawi to provide opportunities for students to extend their knowledge, to raise questions to challenge current views and to learn skills of investigations. His conclusions are themselves very challenging to science educators: that it is relatively easy to devise investigations based on local science and technology; that it is much harder to generate among science educators enthusiasm for and confidence in such an approach; and that it is equally difficult to infuse community based, investigatory science and technology into school syllabuses, teacher training curricula and selection examinations at all levels.

If the debate is to be resolved in favor of this environmental approach, I believe two questions have to be dealt with. First, is this approach intellectually coherent and sufficiently closely matched to the needs and aspirations of low income countries, or will it come to be labeled as a second class curriculum? Second, can the approach be properly applied in the rural primary or junior secondary school with very large classes and minimal resources?

The evidence available is very limited, and nor all positive. The literature contains examples of existing, one-off project activities, ranging from the study of traditional iron extraction methods in northern Uganda to a host of investigations of local alcohol production. There is the experience of Zambia, where a compulsory project became of national third year secondary examinations, since discontinued when the projects became stereotyped and almost entirely paper and pencil products. A similar project may be undertaken as part of the 12th grade chemistry examination in Papua New Guinea. A less radical approach is that advocated and worked out by Swift in his important book, Physics for Rural Development (1983). The starting point here is the given physics syllabus for Kenya, examined after four years of secondary schooling. The existing aspect of the book, which is really a guide to teaching methodology for Physics teachers, is that all the practical physics experiments are chosen with two criteria in mind first, the context for the experiment is one which may reasonably be expected to be familiar to an average Kenyan student; and second, the equipment to be used should be available locally.

These examples are intrinsically interesting, but only provide indirect clues as to ways forward. Each of them has as a prerequisite a level of teacher confidence and competence which cannot be assumed to be widely present. Although clarity of aims for practical science must be a national/regional priority, questions about necessary resources for delivery are very closely related, and will be addressed in the next section before a synthesis is essayed. Providing the resources since the early 1970s, a substantial literature has grown up documenting attempts to solve the problem of major resources deficiencies for teaching science in nearly all low income countries. It is piecemeal and often depressing because the contributions, although manifesting great enthusiasm, are frequently not integrated into a coherent policy for delivering practical science, and sometimes actually promote equipment development which is simply not appropriate. For every country, there is a range of ways of providing resources and equipment for practical science, which will includes; improvisation by teachers in school; in-service workshops for equipment production; nationally produced equipment; and imported equipment. In a fully articulated system, all four elements will contribute to the provision of appropriate resources matching the needs of practical science in the curriculum. Each will now be considered in turn.

Improvisation by inventive teachers developing ideas for apparatus and experiments in their own work environment is hardly a new phenomena it is a very creative activity, traditionally close to the hearts of physics teachers in particular, and to famous scientists like Rutherford who coined the phrase string and sealing wax to describe certain approaches to experimentation. The store of ideas in science teachers journals round the world is tribute enough to teacher’s ingenuity. But it is certain that it will not be occur in those countries where teachers are unreliably paid and where they frequently have to supplement their income from outside teaching. The kind of creative use of improved equipment often seen in the primary classrooms of industrialized countries does not readily transfer to a primary teaching force lacking professional self-esteem, and to a society where one person’s junk is the next person’s artifact. Nevertheless, improvisation of simple equipment can be justified on a number of criteria, which have been well summarized by Simpson (1972):

1. It is cheaper, so that there is more apparatus available for individual or small group experiments, in addition to teacher demonstrations.
2. Concern over loss, breakage and repair is reduces, therefore equipment is more frequently used.
3. Students are made aware of scientific principles applied to everyday things, not just those associated with special apparatus imported from abroad.
4. Attention is drawn to the need to estimate accuracy.
5. Students can see where inaccuracies arise and can see the need for more sophisticated designs for many purposes.
6. A classroom can often be used if a laboratory is not available.
7. Simple equipment encourages students to make good use of local resources and enhances self-reliance.
8. Simple experiments often demand an understanding of basic principles rather than the following of a set of complex experimental instructions.

Teachers working together in in-service workshops to produce materials to carry back to their own schools have, in the past, been a popular model for alleviating local equipment shortages. It has often related to the first flush of enthusiasm for practical science resulting from the introduction of a new curriculum. The benefits of such an approach are considerable development of teacher’s practical skills, production of useful apparatus, and camaraderie among teachers sharing professional expertise. However, the approach has limitations related to quality control, safety and use of teacher’s valuable time. Similarly concerns surface when the in service workshop is extended to in service production of equipment involving students in the construction work. Undoubtedly the most sophisticated example of the genre has been that provide by Krishna Sane of Delhi University, who has targeted his workshop production at a higher than unusual age range, focusing his efforts on making chemical instrumentation for senior chemistry students. The designs and products include PH meters, colorimeters and conduct meters. Sane’s approach has been widely replicated, with evaluation suggesting that quality control has been maintained, and that product costs are of the order of 10 percent of commercial equivalents for comparable performance (Sane, 1982).

Perhaps the most important merit of the workshop approach is that it has on occasion led to the development of local science equipment production centers. Many such initiatives have grown up since the early 1970s, on all the major continents. At their best, they reduce dependency on imported science equipment of consistent quality; they involve teachers, teacher educators and curriculum developers at the design stage; they produce equipment closely related to contemporary science curricula in use in the country; and they are commercial enterprises. A common strategy has been to seek to develop kits of apparatus which can be given to schools as part of an integrated package with curriculum materials such as teacher’s guides and student’s workbooks. The kits produced by Kenya’s Science Equipment Production Unit (SEPU), which is based at the Kenya Science Teachers College, contain equipment which allows the teacher to demonstrate crucial experiments. In Zimbabwe, the ZimSci Kits provide for both teacher and student practical work, ZimSci has been particularly successful in utilizing commercial waste materials, and in adopting for uses as science apparatus such long production run items as measures, cans and plastic cups. These kits seem much more likely to be used than those sent to low income countries from industrialized countries, which frequently gather dust. Even in successful production units like those mentioned, there remains the significant danger of copying from a manufacturer’s catalogue while claiming to have made the product locally. And an approach through kits can be criticized as providing a form of packaged science which allows only the demonstration of simple and idealized phenomena, thus frustrating the exploration of real-life situations and problems (Ahmed 1977). Choices King (1986) has expressed the problem most clearly in the more general context of technological development for low income countries, writing particularly of India:

In the developing world, where development has seldom meant more than a mad race to catch up with the West, technological changes (in the North) will pose serious problems. If catching up with the West needed a major commitment in the 1960s and 1970s, it will require the total commitment of all our national resources in the 1980s and 190s. This will raise serious questions of choice. Do we develop our science to stay in the technological race, to enter the 21st century on the terms of the world technological powers? Or do we develop our own science focusing on our land and water resources, on our forests and grazing and on removing the growing environmental imbalances that threaten the very survivor of millions of our country folk?

Applied to our agenda for practical science education in low income countries, this presents us with a number of difficulties. Science for all, perhaps broadly interpreted to include technology, is a legitimate aspiration, at least for primary or basic schooling in low income countries. Acute problems arise when we try to interpret that for secondary schooling, where the familiar trappings of laboratories and equipment designed for small group student science provide unrealistic expectations. Yet we have to note the necessity for low income countries to develop the capacity to respond to relevant scientific and technological advances, such as the implications of genetic engineering in agriculture, through skills of their own nationals. The World Bank (1998) puts it thus: Africa must improve its science and technology training and aim at the highest standards for at least a minimum core of specialists. It is not clear whether the final part of the statement is directed at the level of secondary schooling if it is, readers will have no difficulty in seeing the dilemmas posed for science curriculum planners.

For primary science, where there are already excellent models incorporated in programmes like the Science Education Programme for Africa (SEPA) a predominantly environmental approach is already possible with limited resources, but remains heavily dependent on investment in increased sophistication and confidence in the teaching force, and probably the recognition of such approaches in summative examinations at the end of primary schooling. Current investment in primary schooling in sub-Saharan Africa averages US$0.60 per pupil per year and it has been estimated (World Bank 1988) that a nearly tenfold increase to US$5 per year is needed to provide basically resourced primary schooling, with consequences for many countries of a rise in investment from 1-2 percent of gross national product (GNP) to 3-4 percent.

The case of secondary schooling is more complex. It can be argued that practical laboratory science is just part of a larger disfunctionality in secondary schooling, which relates to issues of credentials. In such an environment it is unlikely that the aims of practical science discussed earlier will be fully unlikely that the aims of practical science discussed earlier will be fully operationalized. Practical science will continue to be seen as luxury which no one can afford, except in the immediate run up to a practical examination. Of course, we could a case for examining practical science indirectly using paper and pencil tests which require the candidate to demonstrate planning, decision making and problem solving skills, but that has very serious logistical implications which have not really been solved anywhere. An interesting example of the beginnings of such an alternatives approach has come from the work of regional groups of physics teachers in Cameroon. Their assessment was that it was quite unrealistic to expect students in the early years of secondary school to have an experience of practical science, given the usual prevailing shortages of resources and huge class sizes. They have prepared workbooks for students which aim to provide an indirect experience of practical science, sometimes through data analysis, sometimes through comprehension of descriptions of completed experiments, sometimes through ‘thought’ experiments. The impact remains to be evaluated and no one is claiming that the approach provides a comprehensive experience of practical science. A radical approach would be to commend an extension of the environmental model from the primary sector to the secondary, matching King’s implied preference, but inviting gibes of second class and neo-colonial. Otherwise the most optimistic view that can be offered involves the use of carefully designed, integrated packages involving Kits of equipment closely linked with curriculum materials which allow the teacher to demonstrate experiments and to offer occasional practical experiences for the students.

Whatever directions are taken the necessary sequence for implementation remains the same. First, clear national aims must be articulated to science curricula and associated practical science. Second, careful judgments need to be made about the reality or practicality of proposals derived for practical science. Third, it should be ensured that there is substantial investment in teacher preparation for delivery of proposals, relating teacher education curricula closely to school realities. Fourth, appropriate investment in facilities is necessary. Fifth, full recognition must be given to all genuinely creative local responses. And all this must be done by indigenous science education.

**Self Assessment Questions**

Q.1: Conduct a research to get responses related to practices in practical from experts.

Q.2: Give suggestions about the expenditures on science practical per student in Pakistan.