Secondary School Science in Developing Countries
Status and Issues

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ABSTRACT

Many of the problems facing humanity today will only be solved through the involvement of a scientifically and technologically informed citizenry. Agriculture, health, nutrition, population control, environmental management, and industrial development are a few of the areas where a wider exposure to science and technology education will lead to more informed decision-making by the political establishment as well as ensure an adequate supply of scientists, engineers, and technicians.

This report reviews the status of secondary school science in the developing world, and explores issues related to the improvement of science teaching and learning in both developing and developed countries. The topics covered include: curriculum content, laboratory instruction, teacher education, and assessment. Non-formal science education, environmental education, and female participation in science are briefly explored in the appendices. The report also examines the World Bank's record of support for science education since 1963, and includes case studies from each of the Bank's regions.

If science education is to be made accessible and useful to all, many countries will have to consider planning for complete systemic change, to be accomplished over a period of about ten years. This should include the coordinated reform of curricula and courses, together with the examination system, and teacher preparation and continuing education. Given the financial constraints in so many countries, the first priority for reform should be the implementation of comprehensive, and continuing, inservice education for science teachers. Science teachers are the limiting determinant of the success of any science education reform in all countries; they should be included as an integral part of all reform activities.
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SUMMARY

Discussion

Across the world, in developed and developing countries, science education is in a position of both privilege and peril. It is privileged because the political world recognizes a relationship between quality research and development in science and technology, and economic stability and growth. In many countries, this recognition has resulted in additional efforts being made to support science and technology education at all levels — it is not necessary to convince national decision makers of the importance of science education, since this is widely accepted already. In addition, in many countries there seems to be a growing recognition that science education is important — not just for scientists, but for the majority of students, both male and female, who will never become scientists (or engineers, or mathematicians). "Science for all" is a rallying cry in many countries.

Herein lies the peril. The expectations as to how much a science literate populace can reshape any given society tend to be too optimistic. It is true that many of the problems facing humanity today will only be solved through the active involvement of a scientifically and technologically knowledgeable citizenry. Agriculture, health, nutrition, population control, environmental management, and industrial development are a few of the areas where a wider understanding of science and technology will lead to more informed decision-making. However, when countries invest limited financial resources in science education and the impact is less than anticipated — or slower in realization — then there may be a backlash against science education that is as extreme in the negative direction as the current trend is positive. This comment does not imply that quality science education is not vitally important for all students in all countries. It is simply a note of caution — a plea for realistic expectations.

There are several reasons for taking this position:

- There is not yet a consensus on how to structure courses that will provide "quality" science education to all students.
- There is a widespread lack of understanding of the complexities of implementing successful educational reform, in both developed and developing countries.
- No country has ever achieved widespread science literacy, however this may be defined. When do you claim success in reaching this goal and how do you measure it?

The issue of exactly what is meant by "quality" science education is a matter of some debate. The discussion tends to focus on curriculum content, with the assumption being that if (this time) science content is defined "correctly," then science literacy will be easy (or relatively easy) to accomplish. The starting premise is that "quality" science education, at both the primary and secondary levels, is accessible, and relevant, to all students. (Although this report focuses on the status of secondary school science, this emphasis is not meant to imply that science instruction in primary school is less important than in secondary school. Quite the contrary is true if "science for all" is to have any meaning in a country where the minority of students attend secondary school.)

* For the purposes of this report, secondary education is defined as grades 8/9-12/13 unless otherwise specified. Pre-university education is a term that is not common to all countries, so comments made on upper secondary education (11/12 -12/13) apply to pre-university education, unless otherwise stated.
In most participating countries, the first wave of secondary science education reform, which began in the late 1950s/early 1960s, was unsuccessful in reaching large numbers of students with scientific information. For some time, the prevailing wisdom has been that these highly academic courses are, at least, an excellent preparation for science studies at university. Now, even this belief is being challenged. However, there is no agreement on how to reform upper secondary school science courses for students who intend to major in sciences at university.

For the majority of students who will study no science after secondary schooling, the new definition of quality science education springs from the utilitarian tradition — important science knowledge is useful science knowledge, and vice versa. Science is considered one way of understanding the natural world, rather than as solely the body of knowledge accumulated through this process. Science is recognized as existing within a societal context. The students' "need to know" science is established through science courses that emphasize the connections between science, technology, and society (STS). Issues and applications (e.g., use of fertilizers and pesticides, sound nutrition, healthy living, etc.) are used both to motivate students to learn science, and to think well of the scientific enterprise.

STS themes are introduced into science classes as either "enrichment" material in otherwise traditional science courses, or they may actually become the organizing focus of the course. Both approaches are found in developing countries, but usually only at the lower secondary level, often in the form of an integrated science course. At the upper secondary level, the impulse toward science for all tends to become subverted by the need to pass a specialist examination for university entrance.

Apart from the need to pass an examination, there is also the issue of exactly when the specialist training of future scientists should begin. Many developing countries can not afford to make any curriculum changes that may be perceived as "weakening" the preparation of future science professionals. Unfortunately, the specialist examination invariably dictates the curriculum, which is so overloaded with "must learn" content, that there is no time left for teachers to bring life and creativity (or modern science) into their classrooms — even if most of them could.

This is the key problem. Between the ideal curriculum and the pressured student (the reality) falls the teacher. The lack of success of the 1960s courses was often blamed (unfairly) on teachers who had a poor understanding of science content. The new science courses are even more of a challenge to teachers because, not only do the courses tend to be interdisciplinary, they require a new pedagogical approach.

Teachers who are uneasy with their subject matter knowledge tend to teach almost solely through lectures. These teachers are being asked to change not only their teaching techniques but their whole concept of classroom management. Role-playing, games and simulations, student-led discussions, and cooperative learning are strategies that are considered helpful in reaching more students with science knowledge. They can only be successfully introduced by a confident, qualified teacher. Not only may these techniques be unfamiliar to the teacher but they may threaten a given culture's definition of an appropriate relationship between teacher and taught — the student-centered classroom is an alien concept in many countries.

The desired qualification for teaching secondary school science in most parts of the world is typically a four-year degree/certificate after 12 years of education. In Latin America and Asia, this is often a joint degree in science and education. In anglophone Africa, at the upper secondary level this is more likely to be a bachelor's degree in science, with a teaching diploma taken separately a year later. At the lower secondary level, this is usually a three- or four-year teacher training certificate/diploma in science education. In francophone Africa, a four-year science education degree is commonly required.

In reality, secondary school science teachers in the developing world have a wide range of academic credentials — from little more than a 10th-grade science education and no pedagogical courses, to the equivalent
of a master's degree in science education. The teachers may have a science degree obtained after 17/18 years of education but have received no instruction in pedagogy. Alternatively, they may have received a pedagogical degree after 15/16 years of education, but have taken very few science courses. Almost any combination is found.

In most countries, teachers at the upper secondary level are expected to have received a more extensive education in the sciences than teachers at the lower secondary level. On first reaction this makes perfect sense - in many countries the science taught at this level can be quite complex. This is especially true in those countries where students specialize in science for two years before entering university.

However, the result of this practice is that the teachers with the poorest understanding of science are found teaching in the pivotal lower secondary school years. These are the years when a student will decide whether or not to continue in the science stream. These are the final years of exposure to formal science instruction for the majority of students in secondary school. These are also the years when teachers are more likely to teach integrated science, or several different sciences. Science teachers at the lower secondary level need as strong a science background as teachers at the upper secondary level, but with a much broader exposure to the range of science disciplines.

There is world-wide dissatisfaction with many science teacher education programs because science knowledge and pedagogical knowledge tend to be taught in parallel, rather than in an integrated fashion. The connections between educational theory, science knowledge, and conveying this knowledge to students are not made explicit, or are not well-emphasized. This is very much a consequence of the institutional, intellectual, and attitudinal barriers between scientists and educators in most countries, developed and developing.

Many secondary science teachers are teaching out-of-field. This is true especially for teachers of integrated science, who tend not to have the wide content background needed, and physics teachers who may have qualifications in chemistry, mathematics, and engineering rather than physics. Teachers with a strong background in physics content (and, to a somewhat lesser extent, chemistry) can often find employment in other sectors of the economy.

The status of secondary school teachers of all disciplines is low in many developing countries, but especially in sub-Saharan Africa and Latin America, where the secondary teachers often have to take more than one job to survive economically. This results in high rates of absenteeism, and an erosion of professional identity. Secondary school teachers in many Asian countries appear to have a higher status in their society than do teachers in Africa and Latin America - teachers in Korea are especially favored in terms of both prestige and pay. Where teachers have status, there is a great deal of competition to enter teaching and the candidates are better-qualified. (There may also be a large pool of candidates when the status of teaching is low, but this is usually related to a lack of employment opportunities in other sectors of the economy, and the perceived stability of the profession. It is not associated with well-prepared and motivated teachers.)

The continuing education of science teachers can be viewed from three perspectives: (i) it is a mechanism to bring all science teachers up to a minimally acceptable level of qualification; (ii) it is an adjunct to the introduction of new curricula/equipment/materials/kits/examinations; and, (iii) it must be provided if teachers, as professionals, are to stay abreast of developments in both pedagogy and subject-matter content. By necessity, the first purpose has become the first priority for many countries. Bringing unqualified teachers up to desired standards may involve support for teacher courses at colleges and universities, distance learning opportunities, the provision of extended workshops and seminars, frequent short courses, etc. These same opportunities are not so readily available in some developing countries for those teachers who have already reached the minimal standards.
Too often, teachers who have already obtained at least the minimally required qualifications receive superficial continuing education only to support the introduction of new textbooks, equipment, etc. There appears to be a lack of recognition of the level of effort necessary to prepare teachers for reform — especially those who are poorly prepared already. This lack of understanding appears to be the most common reason why science education reform is so difficult to achieve in both developed and developing countries. When reform attempts to work around the teacher (programmed kits, so-called "teacher-proof" curricula, radio and TV instruction, etc.) it will always, ultimately, fail. Science educational reform must be accomplished by teachers, not imposed on them.

Laboratory instruction is still considered an essential component of secondary school science classes in most countries. It is easy to suggest that problems associated with implementing the laboratory component of science classes result solely from inadequate facilities, and a lack of equipment and supplies — if this were true, then simply providing facilities, equipment, and materials, would solve these problems. However, too often, laboratories are used only as regular (expensive) classrooms; equipment remains on the shelf unused to prevent breakage, or broken equipment remains un repaired; consumables are not resupplied; and teachers are not shown how to use and repair equipment. Many of these problems are, at least partly, a consequence of teacher insecurity with the subject matter, and a failure to include adequate teacher continuing education in implementation plans.

Laboratory skills may, or may not, be included on the examination which is driving the curriculum. If laboratory work is not tested, it is probably not taught. There is also the issue of exactly what the objectives of laboratory instruction should be and how achievement of these objectives can be measured reliably. There remains the unfilled need to reconceptualize the role of the laboratory in science instruction both for reasons of pedagogy and cost.

Assessment in the developing world tends to concentrate on student selection and certification, rather than be viewed as an opportunity to determine what does or does not work within the system (formative assessment), and then make appropriate adjustments. Participation in international comparative studies of science education has provided the few developing countries which have participated with valuable base-line data from which to introduce informed change. It is unfortunate that more countries have not the resources, financial or otherwise, to take part in future international surveys, or, through some other mechanism, to collect quantitative data from which to plan reform.

The relationship between the curriculum and the standardized examination distorts the system, making curriculum reform an especially hazardous undertaking. Just as the teachers are an essential component of science education reform, so is the examination. The assessment system is so important that it has even been suggested that the ideal curriculum will follow the ideal examination, not precede it.

Each component of the system (the teachers, the curriculum, and the examinations) is inter-related — and each has its own problems to solve. However, science education reform will achieve its more ambitious goals only through systemic reform. While this may suggest the need for revolutionary change, this reform will only be successful through an evolutionary, rather than revolutionary, process. It will involve coordination of problem-solving among all stakeholders in the process of reform; it will depend on sustained political commitment; it will take great organizational skill; it will require much patience; there will be a need for many midcourse corrections; and it will be expensive. However, the results will be worth the effort.
Recommendations

(i) Teachers

1. In most developing countries, science education reform should begin by concentrating on ways to improve the continuing education (inservice and onservice) of secondary school science teachers. There are larger numbers of unqualified teachers already within a given system, than enter teaching each year. Many of these teachers are young, and likely to remain in teaching for many years. Lower secondary school teachers should be considered a higher priority than teachers at the upper secondary level, if this choice must be made. This continuing education should include both science content and pedagogy. Continuing education should be viewed as an ongoing necessity for all science teachers — both those who are poorly qualified and those who are defined as well-qualified. The former group should be given the first priority when resources are scarce. The use of well-qualified, and specially trained, secondary science teachers to run inservice education programs for less-qualified teachers (through, e.g., "cascade" workshops) addresses the needs of both groups, and should always be considered.

2. This effort needs to proceed from an action plan that includes both quantifiable goals, and a meaningful evaluation system. The goals should specify the numbers of teachers to be reached per year of the action plan; the number of contact hours of instruction to be provided; and the educational outcomes anticipated. These outcomes should be expressed in terms of teacher credentials and teacher classroom behaviors, as well as student enrollments in science classes, and student achievement. The evaluation should be formative and ongoing, and used as an opportunity to refine the action plan as dictated by experience. All efforts to provide inservice education to secondary science teachers should include a well-funded, and educationally meaningful, evaluation component. Also, teachers should have an opportunity to evaluate the effectiveness of the instruction they receive.

3. Since it is true that teachers tend to teach the way they were taught, the teacher educators (for both preservice and continuing education) must simultaneously be targeted for additional coursework. This is to ensure that teachers (i) are exposed to modern views of science, and (ii) see the new teaching techniques they will be expected to use, effectively modelled by their instructors. Otherwise, past inadequate science comprehension and poor teaching practices will continue to be reinforced by ill-prepared teacher educators. Of special importance is giving the teacher educators support with integrating science content and teaching techniques.

4. In many, but not all, countries, there is a need to reevaluate the content of teacher preservice education. A knowledge of both science and pedagogy is necessary for effective teaching but the balance of each component may need adjusting. It is important to broaden the teacher's science knowledge to cover more than one discipline, especially at the lower secondary level, and to purge the superficial from the pedagogical component of the program. "Practice" teaching under the direction of a "master" teacher can be of special value to novice teachers.

5. No attempt should be made to shorten the training of secondary science teachers to less than four years of post-secondary study. Where the requirements are currently less, efforts need to be made to raise the entry standards through restructuring preservice education. Where this is not feasible for economic or political reasons, efforts should be made to ensure that all secondary science teachers have the opportunity to meet some minimal, specified requirement within a clearly defined time period after entry into teaching. This time period will clearly
depend on each country's capacity to support the effort, as well as the magnitude of the problem.

6. All reform efforts should include teachers as part of the reform process. This could be accomplished through assigning special responsibilities to the science teacher organizations, and giving them the financial support necessary to meet these responsibilities, as well as through involving qualified teachers in running their own continuing education programs as mentioned above.

7. Ways must be found to improve the morale of teachers in all ways a given country can afford. While it may be completely financially and politically unrealistic to call for higher salaries for teachers, it is even more unrealistic to expect a high degree of professionalism from teachers who must hold on to multiple jobs in order to survive. There is a need to provide special rewards to master teachers, either in terms of monetary, educational, or non-cash perquisites (see also Chapter 6). Raising the morale of existing teachers, through a special recognition of their efforts at professional enhancement, will help attract higher quality applicants into teaching.

(ii) Curriculum and Assessment

1. No efforts should be made to change the content of the curriculum without also changing the content of the assessment process driving the system.

2. At the lower secondary level, the curriculum needs to develop a more utilitarian focus. It is probably sensible to begin by gradually adding relevant societal content to existing courses, since this is a strategy which can be implemented relatively quickly, and with less expense, than a major rewrite of the syllabus. This is also a strategy which is less threatening to teachers, and can be used to give them writing experience. Some material will have to be dropped from the existing syllabus if new material is to be added; once again, the new material should appear on the external examination, and teachers should attend workshops on how to integrate new material into existing courses.

3. While, in some systems, a complete overhaul of the secondary science syllabus may be postponed a few years, it will eventually become necessary in most countries if science literacy for all is to have any meaning. Few of existing secondary science courses are designed to meet the needs of the students now taking these courses.

Many industrialized and developing countries have produced excellent new instructional materials. Teachers in other developing countries need a wider exposure to these materials, not for purposes of wholesale adoption, but to prevent "reinventing the wheel." Adoption of these materials without adaptation is not recommended for two reasons: (i) teachers need an opportunity to go through the process of materials development as part of their continuing education; and (ii) the best of the new science materials are written from a specific cultural context, and thus must be adapted if they are to be effective in reaching students from a different culture.

4. It is not yet clear how science for the science stream at the upper secondary level should best be reorganized and redefined; therefore no specific changes are recommended for this group at present. Teaching the pre-university science stream in special science schools is one option
that could be cost-effective, and permit students to gain experience in project work and research, using university-calibre instrumentation and computers.

Reform of science instruction at the upper secondary level will have to be undertaken eventually, but only in conjunction with changes in the first few years of science instruction at the tertiary level. The direction of change is likely to erode traditional discipline boundaries, and thus may be strongly resisted by the more conservative university departments. Thus, it is recommended that a separate study be undertaken of the range of instructional concerns in developing countries related to the school/university interface for science majors.

5. Many countries need to change their assessment system so that it does not impede science education reform, but promotes constructive curriculum revision.

(iii) Laboratory Instruction

1. There is a need to redefine the role of laboratory instruction in all countries. Given the poor utilization of laboratory facilities and equipment in many countries, it is a waste of time and effort to continue to support the construction and provision of traditional laboratory facilities without a very careful review of proposed projects prior to funding. For example, there should be a known relationship between equipment requested and specific curriculum objectives; equipment lists should be developed by educators familiar with the curriculum; and teachers should attend workshops on how to use the equipment.

2. However, laboratory instruction is an important component of science learning and should be retained in some fashion. Low-cost equipment of a sufficiently high standard for use in school laboratories can be produced locally. Only rarely should it be necessary to import equipment because it is cheaper than local equipment. If inexpensive equipment can not be produced locally, then there needs to be both an educational and a management study conducted to find out why. There are no sound pedagogical or financial reasons why extensive and sophisticated instrumentation should be purchased for demonstration purposes only. There is a need to analyze, on a country-by-country and course-by-course basis, the cost-savings possible through maximizing the use of low-cost equipment. Given the extraordinarily high costs of traditional equipment, this study could encourage many more countries to explore the low-cost option than do at present.

3. Teachers do not have the time to make simple equipment themselves and should not, routinely, be expected to do so. However, teachers do need to be able to repair the equipment they have; workshops should be provided to give them the simple maintenance skills necessary. If a system uses laboratory technicians then they should receive equipment maintenance training as well.

4. Laboratory skills should be included in examinations as part of a clearly defined, continuous assessment component, for which the classroom teacher is responsible and receives training. Ways will have to be found to safeguard the integrity of these examination results.

These recommendations are not given in rank order unless so indicated, because it is not possible to define one set of priorities that would be appropriate for all developing countries. It is also not valid to rank these recommendations by a country's economic status, since many of the factors limiting successful secondary science achievement are country-specific not income-specific. For example, some very poor countries may have a larger percentage of well-qualified teachers than some relatively rich countries; it depends on
previous government policies, not comparative wealth. Most countries do need to consider systemic reform but, as indicated previously, through deliberate and sustained evolution not revolution. The time period for systemic reform is closer to ten years than five. However, the one issue which should be first addressed in most countries is the education of science teachers, especially their continuing education given the large number of unqualified young teachers now working in many systems. Teachers are the limiting determinant of reform in any classroom; they need support; they need recognition; and, most importantly, the profession is due respect.
CHAPTER 1

THE CURRICULUM

The Importance of Science Education

In recent years, a number of countries, faced with a decline in undergraduate student interest in majoring in science, mathematics, or engineering, have begun to agonize over whether or not they will be able to produce enough technically trained personnel over the next decade to sustain economic growth. This concern has been fueled by the generally accepted dictum that there is a relationship between science education and economic development, whether or not this relationship has been empirically established to the satisfaction of all (Haddad, et al., 1990; Walberg, 1990; Matthews, 1989; U.S. National Science Board, 1988; National Governors' Association, 1987). The high overall performance of Japanese students of varying ages on the Second International Science Study has certainly become coupled in the press, and the political mind, with the strong economic performance of Japan.

Clearly, there has never been a moment in human history when it has been more important to have at least some minimal understanding of science and technology. We live in a world driven economically by technological innovation. Science contributes to the quality of life on this planet in so many areas: health, nutrition, agriculture, transportation, materials and energy production, and industrial development. Science will ensure that the air we breathe, and the water we drink are life-sustaining and not vectors of disease and decay.

In 1979, the International Council of Scientific Unions-Council on the Teaching of Science (ICSU-CTS) summarized the importance of science education to economic development as follows:

"Long term sustained growth can be assured only if the money invested in science and technology is matched by the provision of funds for complementary educational programmes directed both to the preparation of scientists and technologists and to the improvement in science literacy of the population as a whole... At all levels from the ubiquitous "man-in-the-street" to the most influential ministers, there is a tendency to take education for granted. But unless it is supported on the necessary scale, long term development will not be successfully achieved."

Science in the School Curriculum

The extent to which countries in both the developed and developing world have recognized the importance of science, mathematics, and technology education is reflected in the results of a UNESCO study conducted in 1984. Some 97 countries replied to a survey on the place of science, technology, and mathematics in the primary and secondary school curriculum (levels variously defined). The survey determined which courses were taught at which levels, and for how long a time. There were also questions on the role of practical work in science classes (see Chapter 2).

At the primary level, science was rarely taught as a discrete subject, more often appearing as a component of other courses, especially environmental studies (UNESCO, 1986). It should be noted that, at both the primary and secondary levels, there was no consensus on the meaning of the term "technology," which now seems to include the traditional crafts, home economics, and computer literacy.

Regional and world summary data in science, mathematics, and technology for the primary years are shown in Table 1.1, to provide a context for understanding the situation at the secondary level. In grades 1-2, some aspects of primary science are taught an average of 2.0 hours/week in Africa, 1.9 hours/week in the Arab States, 2.9 hours/week in Asia and the Pacific, 2.1 hours/week in Europe, and 2.5 hours/week in Latin America and the Caribbean. In grades 3-6, this increases to 3.4 hours/week in Africa, 2.6 hours/week in the Arab States,
2.9 hours/week in Asia and the Pacific, 2.8 hours/week in Europe, and 3.0 hours/week in Latin America and the Caribbean.

TABLE 1.1
Science, Mathematics, and Technology in the Primary Curriculum (UNESCO, 1986)

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N = Number of countries
At the lower secondary level (grades 7-9), integrated science courses were common in the Arab States, Africa, and Asia. Other courses available at the lower secondary level included general science, physical science, and biological science. At the upper secondary level (10-11/12/13), biology, chemistry, and physics were the most frequently offered courses. Also offered at the upper secondary level were agricultural science, earth science, and astronomy. Table 1.2 provides data from this survey and other sources that illustrate the range of science offerings worldwide. Courses are more likely to be compulsory at the lower secondary level, and optional at the upper level, although this is by no means uniform.

Of special interest are the data on the amount of school time devoted to science, mathematics, and technology, since the time spent on instruction is associated with how much learning can take place (Walberg, Harnisch, and Tsai, 1986; Postlethwaite, 1975). As shown in Figure 1.1, at the lower secondary level students around the world are spending an average of 5.9 hours/week (22% of the available time) on science instruction. Worldwide the range is between 1.5 hours/week and 9.9 hours/week. The regional averages were 5.6 hours/week (21% for Africa), 3.7 hours/week (13% for the Arab States), 5.9 hours/week (22% for Asia and the Pacific), 6.4 hours/week (23% for Europe), and 6.7 hours/week (25% for Latin America and the Caribbean). Since the published data do not include the number of weeks of instruction per year in each country, it is difficult to interpret this data accurately. However, if instructional time is an indicator of relative importance, then the Arab States seem to place less emphasis on science instruction than other countries.

Mathematics, "the handmaiden of the sciences," is compulsory at the primary and lower secondary levels; it is less likely to be compulsory at the upper secondary levels for all students, except for those in the science stream. Of special note is the integration of mathematics with science in the lower grades in Brazil and Chile.

Caillods and Göttelmann-Duret (1991) recently discussed data from a more recent survey of science education in 11 developing countries, and France and Japan, conducted by the International Institute for Educational Planning. This survey included data from four African nations (Botswana, Burkina Faso, Kenya, and Senegal), two Arab States (Jordan and Morocco), three Asian countries (Korea, Papua New Guinea, and Thailand), and two countries in Latin America (Argentina and Chile). At the upper secondary level, these countries provide science and mathematics courses of two and/or three years in duration for both the science and the non-science streams.

For most of these countries there was a great difference in the number of hours of instruction for the science stream versus the non-science stream, indicating a strong emphasis on pre-university specialization. For example, for the three-year program in Morocco, specialists in the natural sciences were reported to take 768 hours of science instruction compared to 64 hours for the non-science stream. For the three-year program in Botswana, students specializing in science took from 720 to 1,008 hours of instruction compared to 432 hours for the non-science students. Burkina Faso also distinguished significantly between the two groups of students (849 hours for science specialists, no data given for non-specialists). However, this distinction is not true for Kenya or Chile, where for the second two years of secondary schooling the time spent by all students on science instruction was 416 hours in Kenya, and 336 hours in Chile. The other countries surveyed tended to fall between these time limits for both categories of student.

The type of science course taught at the upper secondary level tends to depend on the extent to which specialization takes place before university entrance. In a separate study, the International Council of Associations for Science Education (ICASE) has identified some 128 integrated science courses taught at all levels worldwide. The majority of these courses were offered at the lower secondary level (62); at the upper secondary level there were only 29 courses, while the remainder were offered at the primary level, at teacher training colleges, at universities, and in adult education programs (Chisman, 1990). Integrated science refers to courses where more than one science is taught in the course in an interdisciplinary context, whereas general science usually involves the teaching of more than one science in a course, with no attempt at integration.
### TABLE 1.2
Secondary Courses Offered

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Key: L = Lower secondary (usually S1-S4), U = Upper secondary (S5/S6), B = Basic secondary, D = Diversified secondary, PU = Pre-university, GS = General science, IS = Integrated science, PS = Physical science, BS = Biological science, B = Biology, C = Chemistry, P = Physics, OTH = Other (often agricultural science)
Figure 1.1
Science, Math, Technology, Gr. 7-9
(UNESCO, 1986)

Percentage of time

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Hours per week

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The courses were offered to students of "average" ability (81%), "higher" ability (14%), and "lower" ability (5%). Most of these courses originated in their country of use (76%), while the remainder were adapted, with varying degrees of modification, from courses used in other countries. Chisman reported an apparent trend toward organizing integrated science courses around either the processes of science or the environment (as compared to a previous ICASE survey conducted in 1978).

Supporting written materials included textbooks, worksheets, teacher's guides, curriculum guides, and tests. The majority of the courses identified by Chisman were in English. Audiovisual materials available included slides, audiotapes, videotapes, films, games and simulations, and TV and radio programs. The laboratory component of each course varied from 25% to 75%.

Neither the ICASE nor the UNESCO studies provided information on how each country defines the content of science courses, nor on how this content is taught, or by whom. These are important questions to answer since, over the past decade, the issue of exactly what is "science" education has become a matter of some debate.

What is Science?

Science may be defined as a way of understanding the workings of the natural world. Too often, the "facts" of science (the explanations themselves) are understood to be all of science, which, by definition is much broader than the body of knowledge it accumulates. The "facets" of chemistry proposed by Kempa (1983) can be modified to describe the characteristics of science.

Science is:

- A body of information and explanation about the natural world and all it contains
- A way to generate and test new knowledge, and gain insights that allow problems to be solved
- A human and cultural activity that influences the way in which societies develop and prosper
- A subject with personal applications and uses
- A subject with applied industrial, agricultural, economic, and technological uses
- A subject of major social, environmental, and societal importance

Modern science education should be the process of conveying all these characteristics to students. Over the past 30 years, science curricula have tended to emphasize only the first two characteristics, an emphasis that is increasingly under attack. As a result, we are now in a period of reexamining what most appropriately constitutes "science" education, or in trying to answer the question, "What science is worth knowing?" The answer is, in the real world, a matter of policy selection.
Science Curriculum Policy

Roberts (1988) has defined science curriculum policies as "official, legally binding statements of what counts as science education." He points out that the definition of "what counts" as science education goes well beyond the science topics that are taught to include the contexts in which they are taught. He calls these contexts the "curriculum emphases" and has defined seven that need to be considered when contemplating curriculum reform (c.f., Kempa, 1983). They are:

1. **Everyday Coping:**

   The emphasis is on the direct utility of the course to the students. Science is viewed as necessary to the understanding and control of the world in which the student lives. For example, the GCSE-level Salters Chemistry approach (UK) introduces chemistry facts and concepts through everyday topics such as "Food," "Clothing," "Buildings," "Keeping Clean," and "Fighting Disease," etc.

2. **Structure of Science:**

   The emphasis is on the nature of the scientific discipline being studied. Science is viewed as a powerful intellectual system governed by a scholarly elite. The Nuffield Science courses (UK), and the 1960s NSF-funded reforms in the United States (the so-called "Alphabet curricula) evolved from this particular emphasis, which has also been widely adopted in many developing countries.

3. **Science, Technology, and Decisions:**

   The emphasis is on the relationship between science, technology, and problem solving related to societal issues. The students, as future citizens, will have a role to play in shaping the ways in which science and technology develop within their community. Two STS texts from Canada, *Science: A Way of Knowing* (Alkenhead, 1975), and *STS Chemistry: Science, Technology, Society, and Communications Chemistry* (Author Group, 1988), fall into this category.

4. **Scientific Skill Development:**

   The emphasis is on the processes of science—the ways in which scientific information is collected and accumulates. Science is valued as a way of knowing. The science curricula developed by the Institute for the Promotion of Teaching Science and Technology (IPST) in Thailand have this particular emphasis.

5. **Correct Explanations:**

   The focus is on the facts and explanations of science. These explanations are viewed as both "correct," and immutable. The 1950s way of teaching science in most parts of the world tended to emphasize the "received wisdom" approach.

6. **Self as Explainer:**

   The emphasis is on exposing students to the thought processes of influential scientists as those scientists developed their explanations for natural phenomena. The intent is to give students insight into how knowledge accumulates in science. A course which places science in its historical/philosophical context would have this particular emphasis. The U.S. Beckmann Center for the History of Chemistry is interested in developing instructional materials with this particular focus (Benfey, 1990).
7. **Solid Foundation:**

The focus is on preparing for the next level of education (or for the next standardized examination). The primary course prepares for the secondary, and the secondary for the tertiary. The end-product of this approach has a doctorate in science! A variation on this emphasis is to use the examination, not as a means of preparing, but as a means of selecting those few students permitted access to the next level of education.

Roberts points out that: any one curriculum may include more than one emphasis, but not, by definition, simultaneously; and, there is a minimum period of time needed to develop any given approach. The seven emphases clearly fit into the three basic traditions: the academic (Structure of Science, Scientific Skill Development, Correct Explanations, and Solid Foundation); the utilitarian (Everyday Coping); and the pedagogic (Self as Explainer, and Science, Technology, and Decisions).

Roberts stresses that there is no "correct" or best selection of emphasis. The choice is made for sociopolitical reasons. It will depend on economics, national priorities, political ideology, religion, or even "fads-of-the-time." However, to the extent that the academic tradition has higher status among teachers, it might be assumed that teachers are more accepting of reform efforts that emphasize the academic tradition. Their students may be more accepting of a utilitarian approach, depending on whether or not they view themselves as future scientists. Other stakeholders in the process of curriculum reform within that same system may also be predisposed to a particular, and different, emphasis. Thus, the science curriculum reform effort should always begin by establishing a consensus on curriculum emphasis among all the stakeholders (science educators, educational administrators, teachers, parents, students, employers, economists, politicians, etc.). However, in the real world, curriculum reform is only rarely built around such a consensus.

Despite Roberts' contention that there is no one "correct" emphasis, the collective world experience over the past 30 years strongly suggests that science taught exclusively from the academic tradition can never reach the majority of students (see following section). Hence, there may be more "appropriate" emphases, depending on whether the target audience is to be the future scientist, or the future citizen. Exactly which emphasis is most "appropriate" if "science for all" is the ultimate goal, is currently being explored in classrooms all over the world. There has been much less attention paid to the need to reform the secondary school curriculum for the future scientist — perhaps for historical reasons.

**The First Wave of Science Curriculum Reform**

Thirty years ago, the United States (with the NSF-supported "Alphabet" curricula) and the United Kingdom (with Nuffield Science) began the reform of primary and secondary science curricula that was to spread, often with few modifications, to the rest of the developed and developing world. For this first wave of reform there were two generally accepted purposes: the initial training of the next generation of scientists, and a belief that science knowledge was in some way important to the intellectual development of all students. The second purpose was soon to become subordinate to the first.

The pre-reform courses, which did have some merit in that most included examples of science applications, could fairly be criticized for their overload of unrelated facts. The new courses were purged of relevance to give primacy to the "structure" of the discipline being taught. They were highly abstract; they attempted to introduce students to the supposed way in which "real" scientists (implicitly defined as academic research scientists) went about the business of "doing" science. Laboratory activities were designed to permit students to experience "genuine" scientific discovery. Science was considered an objective, culture-free, value-neutral intellectual pursuit explored by the most dispassionate of men (gender choice deliberate). Science was
viewed as a body of knowledge, and as a way to generate and test new knowledge, but the human component
of science was ignored (Fensham, 1988).

After a few years of trial in the real-world of the classroom, it was initially accepted that these courses
were fulfilling their first directive (i.e., channelling students into science careers). Apparent success was
measured mainly in quantitative terms -- the number of students graduating with a degree in science or
engineering. If there was no problem with the supply of technical personnel (and in a number of countries in
the developed and developing world there were, and are, surpluses of trained scientists and engineers), then the
courses were considered to be achieving their prime directive -- feeding the so-called "quantitative" pipeline.

However, all over the world larger percentages of students gained access to secondary school education
(see UNESCO Statistical Yearbooks). As more of these students took school science, it was recognized by many
educators that the current courses were not meeting the educational needs of the majority of students then
enrolled (Yager, et al, in press; Pujol, 1990; Fensham, 1988; Lillis and Lowe, 1987; Benard and Waddington,
1983). In the late 60's, the difficulty of these courses in some way added cachet. Ten years later, in many
countries, they were considered too difficult, too abstract, too irrelevant to the real world in which students live.
Where science classes were elective, student enrollments began to decline (Fensham, 1988).

After the first burst of enthusiasm, it also became clear that these courses were difficult to teach. Ideas
of intellectual delight to practicing scientists are not aesthetically appreciated by most teenagers (or adults for
that matter). The difficulty for teachers was very much in providing a motivation to learn, when the "need to
know" the science was not structured into the curriculum. There was no recognition that science is understood
from the perspective of different cultural contexts (Lillis and Lowe, 1987; Knamiller, 1984). There were also
problems related to the teacher's background knowledge of science, as well as fundamental flaws in the
application of "discovery" or "inquiry" learning in the classroom (Welch et al., 1981). The laboratory equipment
and kits, which were a part of some of these courses, were usually expensive. Unused kits, or kits in need of
repair, sat on the shelves in laboratory stock rooms in both developed and developing countries.

Over time, the intellectual calibre of entering science majors began to cause dismay among university
professors, especially in the United States. One problem was that students did not actually understand all the
concepts they could successfully use in numerical problem-solving; another was the inability of students to use
reason to solve problems rather than algorithms (Staver, 1989; Swamy, 1987). These complaints were common
to many countries for all the sciences, but especially for chemistry and physics (Champagne, et al., 1985; West,
et al., 1985). It is regrettablel true that while the pre-reform courses expected students to memorize many facts,
the 60's reform courses resulted in students memorizing concepts. (In fairness, it should be noted that the 60's
reform courses still have their defenders.)

University science faculty in many countries were (and still are) culpable in their insistence that so many
concepts be covered before university entrance. The explosion of scientific knowledge that has crowded
the undergraduate curriculum has been passed down to the younger grades, where the content overload has caused
many potential young scientists to make other career plans. It is this career selection away from science,
mathematics, and engineering which is driving so much of the concern about the quality of U.S. science
education, especially because of the now recognized connection between science and technology education and
economic development.

Walberg (1990), in his report to the World Bank on school science, concluded from the work of Fischer
(1985) and Rogers (1983) on leadership and innovation that "science knowledge as a part of general education
can contribute to the diffusion of science-driven innovation." He cited one study that showed a significant
correlation between the average science tests scores of 14-year-olds and national economic growth a decade later
(Walberg, 1989). He also made the point that early learning in any subject enhances later learning in that subject
special significance in science where an understanding of complex concepts depends so much on previous knowledge (Walberg, 1990; 1989).

In addition, there is a strong research base that supports the value of early, positive exposure to science as a means of keeping more students (especially young girls) in the science pipeline for as long as possible (see, for example, the review of Ormerod and Duckworth, 1975). Thus, it is very important that a student’s first science classes, whether at the primary or lower secondary levels, are structured to encourage, not suppress, student curiosity and wonder about the natural world. It is the belief that the first wave courses are neither reflective of the vitality and creativity of modern science, nor intellectually accessible to the majority of students, that is driving the second wave of science reform.

The Second Wave of Science Curriculum Reform

Much of the momentum of the second wave of science curriculum reform can be credited to the U.K. Association for Science Education which, in 1981, published 12 readers in the series, Science in Society. Other countries were also involved in early reform, including the United States, Canada, the Netherlands, Thailand, Australia, and New Zealand.

While second wave reforms are now being implemented in many countries, this movement has, so far, had a fairly limited impact on science curriculum in much of the developing world. Particularly at the upper secondary level, the first wave courses still predominate, minus the "discovery" approach to laboratory work. At the lower secondary level, the spread of integrated science can be considered a bridge between the first and the second waves of science curriculum reform. However, as shown in Table 1.3, in many countries science curricula still focus on the classical disciplines taught as concepts and facts, with little emphasis on the holistic nature of science, or its utility (Holbrook, 1991).

While the second wave of science curriculum reform has many facets, they can be conveniently summarized under the rubric of "science (and/or technology) literacy for all." The majority of students, who will not become scientists, are targeted by the new approaches to science instruction. Science is viewed both in, and from, its cultural context; the "essential" content is being redefined; and the learner is no longer considered a blank slate on which knowledge can be grafted.

The learner is understood to arrive in class with a personal (and naive) explanation of many natural phenomena already in place. The task of the teacher is to shift the student’s personal (and culturally determined) view of the world toward the scientific. Recent insights from cognitive research are improving our understanding of how students learn science, and why they sometimes find the subject so difficult, thus shaping the way in which the new courses are being designed (see, for example, Driver, 1988; Driver and Oldham, 1986).
TABLE 1.3
Curriculum Emphasis for Selected Countries
(Holbrook, 1991)

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>GRADE</th>
<th>CURRICULUM EMPHASIS/DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Botswana</td>
<td>8-9</td>
<td>Integrated science: academic with some societal topics (1987)</td>
</tr>
<tr>
<td>Ghana</td>
<td>10-12</td>
<td>Academic (science concepts) (1990)</td>
</tr>
<tr>
<td>Nigeria</td>
<td>7-9</td>
<td>Integrated science: academic with themes, societal topics (1985)</td>
</tr>
<tr>
<td></td>
<td>10-12</td>
<td>Single sciences: academic</td>
</tr>
<tr>
<td>Sierra Leone</td>
<td>7-9</td>
<td>Integrated science: concepts with themes (1990)</td>
</tr>
<tr>
<td>Swaziland</td>
<td>11-12</td>
<td>Academic</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>7-9</td>
<td>Academic (1989)</td>
</tr>
<tr>
<td></td>
<td>10-11</td>
<td>Academic (1991)</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>9-10</td>
<td>Academic</td>
</tr>
<tr>
<td>Bhutan</td>
<td>7-10</td>
<td>Academic (1989)</td>
</tr>
<tr>
<td>India</td>
<td>9-10</td>
<td>Thematic with concepts, work relevance; also course on work experience (1988)</td>
</tr>
<tr>
<td>Jordan</td>
<td>S1/S2</td>
<td>Single sciences: academic</td>
</tr>
<tr>
<td>Korea</td>
<td>7-9</td>
<td>Science: academic</td>
</tr>
<tr>
<td></td>
<td>10-12</td>
<td>Single sciences: academic</td>
</tr>
<tr>
<td>Pakistan</td>
<td>9-10</td>
<td>Academic</td>
</tr>
<tr>
<td>Philippines</td>
<td>10-11</td>
<td>(Tertiary) includes science skills</td>
</tr>
<tr>
<td>New Zealand</td>
<td>7-11</td>
<td>Science: relevance, skills, concepts</td>
</tr>
<tr>
<td></td>
<td>12-13</td>
<td>Single sciences: academic (1990)</td>
</tr>
<tr>
<td>Barbados</td>
<td>10-11</td>
<td>Integrated and single science: themes, concepts</td>
</tr>
<tr>
<td>Trinidad</td>
<td>10-11</td>
<td>Science: facts, concepts</td>
</tr>
<tr>
<td>Iceland</td>
<td>8-9</td>
<td>Science: values, environment</td>
</tr>
<tr>
<td>Malta</td>
<td>9</td>
<td>Integrated: concepts</td>
</tr>
</tbody>
</table>

As shown in Table 1.4, which compares the 60s science courses with the second wave reforms, a new role is being defined for the teacher. Teachers are expected to "manage" the learning of students through different pedagogical approaches, including decision-making activities, role-playing, and games and simulations. Students work in groups, conduct library research, and perform laboratory exercises relevant to real-world activities and issues. These new approaches are designed to help students become self-motivated, life-long learners. Holman (1987), who has been especially active in promoting the use of decision-making activities in the science classroom, lists the advantages of simulation games as: improving student motivation; giving students and teachers insight into real life problems; and allowing interdisciplinary learning to take place (see also Chapter 3).
TABLE 1.4

A Comparison Between the First Wave of Science Curricula and the Second
(After Heikkinen, 1988)

<table>
<thead>
<tr>
<th>First Wave</th>
<th>Second Wave</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation for a science career</td>
<td>Science for all students</td>
</tr>
<tr>
<td>Generation of science knowledge</td>
<td>Application of knowledge</td>
</tr>
<tr>
<td>Focus on the discipline</td>
<td>Focus on societal issues</td>
</tr>
<tr>
<td>Broad coverage of content</td>
<td>Less content = more learning</td>
</tr>
<tr>
<td>Science on the lab bench</td>
<td>Science in the community</td>
</tr>
<tr>
<td>Building of conceptual models</td>
<td>Personal decision-making</td>
</tr>
<tr>
<td>Mastery of content</td>
<td>&quot;Ownership&quot; of content</td>
</tr>
<tr>
<td>The teacher as lecturer</td>
<td>The teacher as manager</td>
</tr>
<tr>
<td>Class works as unit</td>
<td>Students work in groups</td>
</tr>
</tbody>
</table>

The precise content of the second wave courses is, not surprisingly, a matter of some debate. There is a "science for all" movement; a science/technology/society (STS) movement; a science/technology/math (STM) group; and a push toward science/technology/craft and design (STC/D). The World Bank and the British Council recently cooperated on the development of an analytical framework for science, technology, and craft education (World Bank/British Council, 1989a). There are a number of such frameworks now available; another example is the framework developed by Jenkins for the Alberta Department of Education (Alberta Education, 1990). In the United States, the National Science Teachers Association (among others) has its own definition of what constitutes STS education (NSTA, 1990). Each approach has its advocates and, while each differs in specifics, there is agreement on what these approaches wish to accomplish — the development of a science/technology literate populace capable both of using its knowledge to improve the quality of life, and of further learning in the evolving work place.

"Science and Technology Education and Future Human Needs," the 1985 Bangalore conference sponsored by the International Council of Scientific Unions-Committee on the Teaching of Science (ICSU-CTS), UNESCO, and ICASE, has been instrumental in accelerating second wave reform in the developing world. The titles of the nine volumes produced by the participants in this conference summarize the range of quality of life issues that are being added to the syllabus, and included in new textbooks and other instructional materials in more and more countries. These are:

2. Ethics and Social Responsibility in Science Education (Frazer and Kornhauser, 1987)
As science is being redefined, the "separate" identity of technology education is also being reexamined. The "new" technology education clearly approaches one subset of the STS movement. The technological skills needed for employment in the future are, increasingly, based on an understanding of science principles. One group, the International Technology Association has developed a conceptual framework for technology education to be taught through "the content reservoirs of bio-related technology, communication technology, production technology, and transportation technology" (Savage and Sterry, 1990). The contributions of biology, physics, and chemistry to these "content reservoirs" are obvious. (There are, of course, other ways of defining the content of technology education but, whatever the final generally agreed upon definition of technology education, technology classes will contain more "straight" science.)

There is also a well-advanced movement to reposition environmental education as a recognized component of all science education (Baez, 1987). For example, as shown in Figure 1.2, in Asia environmental themes are found at the lower secondary level in integrated and general science classes as well as in environmental science, social studies, and a variety of ethical/civic/religion courses (Boh, 1991). At the upper secondary level in Asia, environmental topics are also frequently included in chemistry, physics, biology, and earth science courses (see also Figure 1.2). As another example, ICSU-CTS through its "Global Change" project is heading a multi-national effort to develop science materials related to global environmental concerns (ICSU-CTS, 1991; Waddington, 1991).

As Table 1.5 makes clear, environmental topics are either included in, or are the organizing focus of, many of the more recently developed (and developing) science courses. This reflects the realization that environmentally responsible behaviour stems from a foundation of accurate science knowledge. Environmental education is too important to leave to the well-intentioned but scientifically ill-informed. While man's use of the products of science and technology has caused many of the environmental problems threatening life on this planet, these problems will only be solved by men and women who understand the nature—and limitations—of science and technology.

While a focus on technology or the environment in a science course would appear to be an either/or proposition (i.e., the focus is either technology or the environment), there is even an U.S. chemistry course which claims to address both. Chemistry in the Community (ChemCom) is the widely used, one-year chemistry course designed by the American Chemical Society as a first introduction to chemistry for high school students.
Figure 1.2
Environmental Education, Asia
a) Lower Secondary Level

Legend:
INS: Integrated Science
GSCI: General Science
SOS: Social Science
ENS: Environmental Studies
CHEM: Chemistry
PHYS: Physics
BIO: Biology
ES/G: Earth Science / Geography

Source: Ban, 1991
TABLE 1.5  
Selected Examples of the New "Science For All" Courses

<table>
<thead>
<tr>
<th>Country</th>
<th>Subject</th>
<th>Date In.</th>
<th>Issues/Orientation</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada (Ontario)</td>
<td>Chemistry (upper sec)</td>
<td>1985</td>
<td>Real-world applications, societal</td>
<td>Friesen, 1990</td>
</tr>
<tr>
<td></td>
<td>Physics (upper sec)</td>
<td></td>
<td>implications, attitudes to science</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Science In Society</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>Chemistry (11th grade)</td>
<td>1988</td>
<td>Societal issues, applications</td>
<td>Wase, 1991</td>
</tr>
<tr>
<td>Venezuela</td>
<td>Natural sciences</td>
<td>On-going</td>
<td>Environment</td>
<td>Pujol, 1990</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>Biology and chemistry</td>
<td>Ongoing</td>
<td>Environment (infusion materials)</td>
<td>Davids &amp; Hoekman, 1990</td>
</tr>
<tr>
<td>Norway</td>
<td>Chemistry (11/12)</td>
<td></td>
<td>Environ. topics in 60% of courses</td>
<td>Ringses, 1990</td>
</tr>
<tr>
<td>Portugal</td>
<td>Physics and chemistry</td>
<td></td>
<td>Modules on energy &amp; environ.</td>
<td>Pestuna &amp; Olivier, 1990</td>
</tr>
<tr>
<td>Spain</td>
<td>Science (compulsory)</td>
<td>1990 trial</td>
<td>Environment, energy, technology</td>
<td>Magda, 1990</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>SATIS (science)</td>
<td>1996</td>
<td>STS, applications, attitudes</td>
<td>ASE, 1996</td>
</tr>
<tr>
<td></td>
<td>BSCON (science)</td>
<td>1993</td>
<td></td>
<td>Bolonman, 1993</td>
</tr>
<tr>
<td></td>
<td>Salter Science</td>
<td></td>
<td></td>
<td>Holman, 1990</td>
</tr>
<tr>
<td></td>
<td>Salter Chemistry</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE 1.5 (continued)

<table>
<thead>
<tr>
<th>Country</th>
<th>Subject</th>
<th>Date In.</th>
<th>Issues/Orientation</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egypt/Kenya/</td>
<td>Biology</td>
<td>Ongoing</td>
<td>Future human needs (U.S.-CSE project)</td>
<td>Kelly, 1990</td>
</tr>
<tr>
<td>China/Japan/Germ.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Botswana</td>
<td>Integr. science (low.sec.)</td>
<td>1995</td>
<td>Environment, energy, applications</td>
<td>Chiamin, 1990</td>
</tr>
<tr>
<td>Nigeria</td>
<td>Core science (O level)</td>
<td>1996</td>
<td>Quality of life, applications, utility</td>
<td>Dock, 1994</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>Core science (O level)</td>
<td>1996</td>
<td>Quality of life, applications, utility</td>
<td>Dock, 1994</td>
</tr>
<tr>
<td>Jordan</td>
<td>Science (prim. &amp; sec.)</td>
<td>Ongoing</td>
<td>Environment and energy</td>
<td>Nazer, 1990</td>
</tr>
<tr>
<td>Community-based</td>
<td>Phys.</td>
<td></td>
<td></td>
<td>Talleyson, 1996</td>
</tr>
<tr>
<td>Pakatan</td>
<td>Science (9/10)</td>
<td></td>
<td>Applications, social implications (Non-science stream)</td>
<td>Marria, 1990</td>
</tr>
<tr>
<td>Thailand</td>
<td>Science (low.sec.)</td>
<td>1990a</td>
<td>Attitudes, environ., applications</td>
<td>Soychunum, '90a</td>
</tr>
<tr>
<td></td>
<td>Bio/phy sci (up.sec.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia (Inc.)</td>
<td>Chemistry</td>
<td>1991</td>
<td>STS, environment, applications</td>
<td>VCAB, 1999</td>
</tr>
</tbody>
</table>
In developing this course, it was recognized that chemistry exists in a cultural context and that, through restoring this context, students would be able to understand more chemistry, and develop more positive attitudes toward the subject. Given the economic importance of the chemical industry, and the association of chemistry with environmental pollution, it is not surprising that ChemCom, which is designed around societal issues, focuses on both technology and the environment (Table 1.6).

### Table 1.6
**Technology and Industry Themes in ChemCom**
(Ware, Heikkinen, and Lippincott, 1987)

<table>
<thead>
<tr>
<th>UNIT</th>
<th>ISSUES</th>
<th>TECHNOLOGY/INDUSTRY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>Water pollution</td>
<td>Waste water treatment, municipal water supplies</td>
</tr>
<tr>
<td>Resources</td>
<td>Waste generation; metal resources</td>
<td>Resource recovery, the recycling center, mining, ore extraction, refining</td>
</tr>
<tr>
<td>Petroleum</td>
<td>Depletion of petroleum resources; use as fuel or feed-stock</td>
<td>Petroleum refining, the petrochemical industry, plastics</td>
</tr>
<tr>
<td>Food</td>
<td>Choice of a diet</td>
<td>Food processing</td>
</tr>
<tr>
<td>Nuclear</td>
<td>Disposal of radioactive wastes; exposure to radiation</td>
<td>Nuclear power industry, use of isotopes in medicine, agriculture, industry</td>
</tr>
<tr>
<td>Air</td>
<td>Ozone hole, acid rain, Greenhouse effect</td>
<td>Smokestack industries, the automobile</td>
</tr>
<tr>
<td>Health</td>
<td>Tobacco, alcohol, and drug abuse</td>
<td>Pharmaceuticals</td>
</tr>
<tr>
<td>Industry</td>
<td>Siting of a chemical plant in an imaginary community</td>
<td>Fertilizers, electroplating</td>
</tr>
</tbody>
</table>

The new science courses include quality of life issues/applications in one of two ways: either the science sequence is first developed and the applications are added as appropriate, or the issues/applications are first identified and the science built around the issues. Holman (1987) has compared the advantages and disadvantages of each approach. He has pointed out that "science-first" is easier to implement, since applications can be added on to preexisting courses. Also, teachers may be more comfortable beginning with the science, but may, in the interests of time, leave out the applications when they are only loosely integrated with the science. "Applications-first" is likely to appeal more to students, at least initially. Modular courses based on applications-first permit the revisiting of concepts in different contexts, thus enhancing the students' understanding of the concept.

The Science and Technology in Society (SATIS) materials of the U.K. Association for Science Education, and the Science Across Europe project are two excellent examples of materials that can be integrated into existing courses. Recently, UNESCO has supported several efforts to develop science content frameworks upon which culturally based applications and issues can be imposed (Lawrence Hall of Science, 1990). One such project involves a collaboration in materials development between Dutch, Soviet, and U.S. chemical educators. The Salters Science and Salters Chemistry projects of the University of York are "applications-first" courses. In physics, the Dutch curriculum project (PLON) takes a thematic approach to teaching physics at the upper secondary level (Lijuse, 1988; Eijkelkamp, 1981).
The second wave courses are available in both the traditional textbook format, and as a series of modules from which the teachers and students may select topics. The lack of durability of softcover modules may make them less economical to purchase, but the flexibility to tailor course content makes purchase of modules an attractive option to many teachers in developed countries. In developing countries, the use of textbooks in science classes is an especially important adjunct to the teacher, who may not have much of a science background (see Chapter 3). (See also the analyses of the impact of textbooks on achievement conducted by Lockheed, Vail, and Fuller, 1985; the guide to textbook design and preparation by Read, 1986; and the general operational review of Bank lending for textbooks by Searle, 1985. Since the logistical problems associated with textbook development, production, and distribution are common to other disciplines, no attempt is made in this report to explore these issues yet again.)

"Science for All" vs. Science for a Career

As shown in Table 1.5, newly designed courses in integrated science, chemistry, physics, and biology have been developed, or are being developed, in many countries. As pointed out previously, the new content, as well as the new approach to teaching, tends to be found in courses given at the lower secondary level, rather than the upper secondary. Where systems have a pre-university program for future science specialists, the traditional science courses are still taught.

There is a great deal of concern that the "science for all" approach, even if only implemented at the lower secondary level, will disadvantage those students who are likely to specialize in a science at university. It is difficult to dispel this concern with one simple argument. In school systems where late specialization occurs it is easier to make the case for the "science for all" approach throughout secondary school. In the United States, for example, it is possible to major in a science in college without ever having taken that science in high school. The predictor for success as a science (or engineering) major at U.S. universities is the mathematics taken in high school.

This brings up another extremely important point: for any country the level of achievement in the sciences, especially at the upper secondary level, depends on the quality of the mathematics instruction received by the student. The importance of mathematical knowledge to the study of modern science can not be overemphasized — yet international development agencies do not appear to have clearly recognized the importance of this relationship when funding science education reform efforts in developing countries. There is a need for more research on the relationship between science and mathematics instruction and student achievement at the upper secondary level in developing countries, particularly for the science specialist stream.

In many developing countries there is the need to increase the number of trained scientists and engineers (see Figure 1.3). (This can be true even if there are not yet employment opportunities available to absorb more scientists and engineers in a given country.) Thus, in the developing world the shift of secondary-school science toward the utilitarian may appear to involve a special risk — it may be perceived that students taught in this manner will not be rigorously enough prepared to succeed in university-level science courses.
Figure 13 Scientists and Engineers Per Million Population

b) Low Income Countries

a) Low Middle Income

c) Upper Middle/Upper Income

There is a counter argument. The failure of the first-wave courses to engage the interests of the majority of students, which resulted in early self-selection of many talented students out of the science stream, is one good reason to delay teaching these highly abstract courses as long as possible. This also permits the teacher to reach the larger group of students with useful science information. In developing countries, it is particularly important to keep science knowledge as intellectually accessible to as many students as possible, for as long a period as possible. This will produce not only a more scientifically literate populace, but a larger pool of students from which to select the next generation of scientists and engineers.

Note that the term "science literacy" may be viewed in a number of ways. It may encompass an understanding of (i) the vocabulary and basic concepts of science, (ii) the nature of science, (iii) the ways in which science and society interact. Nowadays, it is impossible to read a newspaper without finding at least one article per issue that uses scientific language and assumes an understanding of certain scientific concepts, as well as the relationship between science and society. School science should at least prepare the student to be able to understand these kind of articles as an adult.

An understanding of the utility of science is especially important in developing countries. For example, the student who becomes a farmer, or who works in an agricultural community, needs to be able to apply both traditional and modern ways of enhancing productivity. The natural cycles need to be understood, as well as ways to enhance crop yields by safely, and cost-effectively, using synthetic fertilizers and pesticides as appropriate. An ability to maintain and repair equipment is also useful.

The health worker needs to understand basic biology including the life cycles of various parasites, and other vectors of human disease. Ways to promote sound community health practices have to be communicated to others in a clear, and unambiguous, fashion. An ability to perform serial dilutions accurately may be the critical factor in saving a human life. A woman who understands the workings of her reproductive system in biological terms may use birth control devices more successfully.

It is important for students to understand the nature of science in order to define its role in their personal and public lives in a realistic fashion -- science neither causes all problems nor has the capability to solve all problems. It is a process through which humans test their understanding of the workings of the natural world. It is not magic, it need not be mystery. An essential component of science is accurate measurement. Ways of measuring different qualities/properties (temperature, volume, mass, length, weight, tensile strength, etc.) using instruments and tools are of practical use in both the developed and developing world.

Students need to learn that science does not exist in a vacuum, but as an integral part of society. Society determines which scientific research is funded, while science and technology contributes to a better standard of living for the community through better health care, more nutritious diets, more effective land use, provision of a steady supply of energy, durable consumer goods, etc. Policy decisions involving the interaction of science with society must be made by informed members of that society, and not just by the scientific elite. Such decisions, which involve value judgements as well as an understanding of science, will determine the future of a country.

Just how effective is the STS approach in reaching students? Research evidence is beginning to build which suggests that, compared to students in more traditional classes, U.S. students who have learned science through a STS framework learn just as many science concepts, in some instances more, and retain these concepts for a longer period of time (Blunk & Yager, 1990; McComas 1989, 1988; Myers, 1988; Yager, et al., 1988). There is also some evidence for the enhanced development of process skills with a STS approach (Blunk and Binadjja, in press; McKinnu, 1991; Yager 1990).

Advocates of STS have claimed that STS students are more likely to demonstrate an ability to apply knowledge than traditionally taught students as measured by: the use of information in new settings; the understanding of phenomena experienced in new settings; the identification of appropriate questions to ask in
problem solving; the choice of information to solve problems; and, the choice of appropriate action based on new information (McKinu, 1991; Yager, 1990). STS is also claimed to enhance attitudes toward science. It should be made clear that most of these studies indicate enhanced performance for U.S. students with well-trained, highly motivated teachers. It is probably fair to say that while much is claimed, much still has to be proved.

There is some evidence that the STS approach is especially well received by young women (McKinu, 1991; Yager, Blunck, and Ajam, 1990). If this proves to be the case, then STS may result in a new generation of creative, and plentiful, female scientists. Also, as Rao (1987) has pointed out, in Africa subsistence farming is almost entirely in the hands of women, and half of Asian women involved in farming are in subsistence production. The disproportionate responsibility of women for food preparation and child rearing make it vitally important to reach girls with useful science knowledge.

The STS approach may not be well-accepted by certain high achievers in science. There is some evidence that selected groups of students from both the United Kingdom and Singapore prefer to study chemistry concepts rather than applications (quoted in Lazonby, 1987). There is also, very preliminary, evidence that chemistry students in the United States with a particular cognitive style (very high in remote association skills) are more interested in concepts than applications (suggested by research into student attitudes toward ChemCom). The ChemCom studies appear to establish a link between the cognitive style of both students and their teachers, and attitudes to ChemCom chemistry (Hogan and Reagan, 1991).

It should be noted that for years science has been narrowly defined to meet the needs of the few students who are academically gifted in science. The needs of the majority, who are not so gifted, have been ignored. A case can be made that future scientists also need a much broader education than they are currently receiving, if they are to function as responsible citizens!

The comments of Fensham (1988) concerning the nature of science instruction for the future scientist vs. science for all are pertinent at this juncture:

*...we shall need to recognize that the two main targets need their own forms of science education and that the second, with its concern for all learners, is the key to the first rather than the first being the key to the second as was the way in the 1960s reforms.*

The Scientifically Gifted

One way to handle the special needs of the scientifically gifted is to identify this group as early as possible, and then provide accelerated instruction in special schools. For example, Turkey, Korea, and Thailand provide such schools for the very small percentage of students in this particular intellectual category (Lewin, 1991). In the United States, there are science "magnet" high schools in many communities, which offer (i) a wider range of science options than other schools; (ii) access to the most sophisticated of equipment; and, (iii) the most highly qualified of teachers. There are also opportunities for scientifically talented high school students to work on summer research projects at local colleges and universities. In the United Kingdom, sixth-form "colleges" may provide an enriching environment for the scientifically gifted.

However, as Lewin (1991) has pointed out, while the tracking of science students may be cost effective (certain resources can be concentrated in a few institutions rather than provided to all), there is no strong evidence that early selection has a significant positive impact upon science achievement. The tracking of the very brightest from an early age may, in fact, disadvantage those not so identified, by confining them to schools with fewer resources and less well-prepared teachers.
At the upper secondary level (or, in some systems, the pre-university level), if there is a high degree of specialization prior to university entrance, only those students intending a career in science will be taking science subjects in the first place. Whether or not it is more cost-effective to concentrate these few students in a limited number of schools, providing boarding facilities if needed, depends on country-specific socioeconomic data. However, if there is not a high degree of specialization expected prior to university entrance, there are no good arguments in favor of differentiating between courses for the future scientist or the future citizen.

While there is debate on exactly what is "appropriate" science instruction for the majority, there has been less discussion on what, and how, to teach the future scientist. Given the interdisciplinary nature of much current research, it is clear that, in the working world of science, the traditional boundaries between the scientific disciplines are being eroded daily. Yet in schools, and in most undergraduate programs, chemistry, physics, and biology instruction is still constrained by the separate historical development of these disciplines.

Reforming the curriculum for the science stream at the upper secondary level is closely associated with reform of the first and second years of university instruction, and should take place in tandem. Exactly how to accomplish this is just becoming an issue, so no consensus has yet emerged on how to reform science instruction for future scientists.

Beginning the Reform Process

As indicated previously, the first stages of science curriculum reform require the building of a communal understanding of a number of issues. These are:

1. The multi-faceted nature of science knowledge (i.e., science is more than facts and concepts).

2. A determination of the group of students to be reached by the reform (future scientists or future citizens or both).

3. A selection of the context from which the science is to be learned.

4. A determination of the science content (there is not time to learn everything).
Figure 1.4

Organization: A Constructivist Model for Curriculum Development

(Driver and Oldham, 1986)
The determination of the specific science content is just one component of the total curriculum design. Driver and Oldham (1986), writing from the constructivist view point, have described three additional inputs (See Figure 1.4). First, there is the collection of information on the students' previous understanding of the content areas to be taught. These are the "naive" explanations that the teacher will have to shift toward the "accepted" explanations in order to achieve scientific understanding. This particular input will depend not only on the students' previous instruction, but on the students' cultural background. The second input, insights from cognitive psychology on how children learn science, will help determine the strategies the teacher will use for instruction. The third component is the practical knowledge of what can be accomplished given the environmental constraints of a particular classroom situation. The curriculum design resulting from these inputs must, of course, be tested in the classroom, and redesigned as appropriate.

The following section will explore curriculum reform in the real world as opposed to the theoretical. Four very different reform efforts will be examined: (i) one which has been successfully implemented in Thailand; (ii) one which is in the early stages of implementation in the United States; (iii) one which is struggling to survive in Zimbabwe; and, (iv) one which is in the early stages of development in the United States.

(i) Development of the IPST Science Curricula

The Institute for the Promotion of Teaching Science and Technology (IPST) was established by the government of Thailand in 1972 as a semi-autonomous agency attached to the Ministry of Education. It was given total responsibility for designing new curricula; developing student and teacher texts; providing training programs for science teachers at all levels; and devising and producing novel and inexpensive science equipment.

The initial development of curricula and texts was a cooperative effort among research scientists, school science and mathematics teachers, and college and university lecturers. The project began with an examination of curricula and materials from all over the world, resulting in a collective decision to take the best from everywhere and shape it into a uniquely Thai science curricula (Soydhurum, 1990a).

The chief curriculum emphasis selected was scientific skill development, i.e., an emphasis on science as a process, as a way of knowing, as a way of accumulating knowledge about the world in which the students live. An inquiry-based instructional mode was selected as most compatible with this emphasis. Materials were trial tested and revised (1976); teacher training was implemented through either the IPST or teacher training colleges; and a research and evaluation component gathered the data necessary to improve the curricula in the light of experience. Revised materials reached the schools in 1981 (see Figure 1.5).

There are eight courses of science developed at the secondary level for both academic and vocational students. (Primary science is incorporated into a subject group called "Life Experiences" developed by the National Curriculum Development Center and not IPST). At the lower secondary level, there is an integrated science program for academic students. At the upper secondary level, biology, chemistry, and physics are offered to the academic stream specializing in science, and physical and biological science to the non-science, academic stream. There are three courses for vocational students: science for agriculture, science for industrial arts, and science for home economics and arts and crafts.

* The constructivist approach to science teaching and learning begins with an understanding that students bring their own explanations of natural phenomena into the classroom with them. They are not an "empty slate" on which scientific explanations can be grafted. The role of the teacher is to shift the students' preexisting explanations toward the scientific. Thus the teacher must first be aware of the misconceptions which students bring with them to class. Then, new knowledge can be constructed from the preexisting.
Figure 1.5

Organization: IPST Curriculum Development Model

(Soydhurum, 1990a)

Curriculum Emphases:

Scientific skill development
Correct explanations
Self as explainer
Practical activities are the organizing focus of the text books, which include data derived from research studies conducted by local scientists. The teacher's guides are comprehensive, including hints on teaching procedures, background information on unfamiliar topics, equipment lists, and lesson schedules. An IPST Equipment Design Team works with the curriculum designers on an on-going basis to develop and test equipment that is: low cost, made from local materials and technology, simple to use, and multi-purposed.

The tension between science for all, and science for future scientists is being addressed in Thailand by the early selection of scientifically gifted students after grade 9, by means of a competitive examination. Students selected attend one of six regional schools where they receive accelerated instruction.

During the period of 1981-1989, Thailand participated in the Second International Science Study (SISS). At the lower secondary level (grade 9), Thai students had a mean score of about 55% of the total score, which compares favorably with the mean score for the same cadre of Thai students who participated in the First International Science Study held 15 years previously (35% mean score). It is also very close to the mean for all Asian countries participating in the survey.

The SISS performance of the Thai upper secondary students (grade 12) in earth science, biology, chemistry, and physics was disappointing (Soydhurum, 1990a, b). Thai students scored below the international mean (23 countries), and the mean for Asia (eight countries) in all subjects except biology. Given the emphasis of the Thai curriculum on process skills, it might be expected that Thai students would perform well on test items related to such skills (the practical Process Exercise Test was not administered in Thailand; a locally designed Science Process Test was used instead). Again the results were disappointing. It was also found that, while Thai students did well on items that tested lower-order thinking skills, they had problems with the higher-level questions.

An item-analysis of Thai student performance on the SISS has led to the following recommendations from Soydhurum (1990a):

- Science content and processes should be more clearly related to everyday life for students in the science stream as well as other students.
- More career information should be made available.
- A greater emphasis should be placed on the relationship between science, man, and the environment.

(ii) Chemistry in the Community (ChemCom)

ChemCom was originally conceived as a course for students who were not planning to study chemistry in college. It was viewed as, possibly, the last opportunity to introduce chemical information to students who would later obtain all subsequent chemical knowledge from newspaper headlines.

Chemistry is an elective course in U.S. high schools. In early 1982, when this project started, only about 30% of U.S. high school students took any chemistry. Most who studied the "traditional" chemistry found it too difficult, too boring, too abstract, and too much of an effort! (This might be considered as much a comment on U.S. students -- or teachers -- as on the curriculum, except that these same descriptors have been heard from students from many countries.)
In attempting to define the context from which the new course was to be developed, ChemCom project staff ignored both the "structure of science," "the solid foundation," and the "correct explanations" emphases to look toward the utilitarian. The academic traditions were viewed as having failed to provide the majority of students with any understanding of chemistry in the real world. The team began to develop a course based on the students' "need-to-know" chemical information. This knowledge was assumed to be both personally relevant (for example, the chemistry of food, hair care, water usage, etc.), and to involve the student as a future citizen and decision-maker. Despite the best intentions of the ChemCom developers, some of the chemistry included is difficult to justify on a "need-to-know" basis — although it is interesting chemistry!

The importance of including teachers in the development of this course was recognized from its inception. The initial materials produced were written by high school teachers; piloted in the schools by a larger group of teachers; and rewritten as a result of teacher and student feedback — all of this before the 1985-1986 field test. The text was revised for the classroom evaluation by a team of chemical educators who had taught at both the high school and college levels. The chemistry content was verified by industrial and academic chemists including one Nobel laureate (Seaborg reviewed the chapter on nuclear issues).

The 1985-1986 field test was critical. It allowed the developers to find out what did, or did not, "work" in the classroom. It was structured so that the majority of the teachers participating received workshop instruction both prior to, and during, the field test. A few teachers did not receive any special training but were only provided with the text and a teacher's guide.

After the field test, it was clear that the greatest problem with this curriculum would be teacher acceptance of the two curriculum emphases of "everyday coping," and "science, technology, and decisions." Teachers worried, "Is this science?" Interestingly enough, this was not a question asked by industrial and academic research chemists, who expressed great enthusiasm for an approach to chemistry that captured some of their own enthusiasm and creativity.

Today, five years later, some 250 teachers have been trained as ChemCom Resource Teachers to take responsibility for the training of other teachers in their own communities. Probably several thousand teachers have received some form of ChemCom teacher training from the Resource Teachers. The status of the Resource Teachers is such that a group of 15 of them recently conducted a series of six workshops in Moscow to introduce Soviet teachers to ChemCom chemistry. A Russian-language adaptation of the text, which is being prepared by the Mir Publishing Company, will be taught across the former Soviet republics in the near future.

Despite all the concern for curriculum reform in the United States, ChemCom is, to date, the only fully implemented second-wave course in the United States. By the end of the 1991-1992 school year, well over a quarter of a million students will have taken ChemCom chemistry. The standardized examination was released (also after piloting) in April 1991. The second edition of the book will be available in April 1992, also revised as a result of teacher, and student, input (see Figure 1.6). The American Chemical Society has funds to support at least four more years of teacher training.

However, it would be premature to call this course an unqualified success. Despite the time (this project began in 1982) and the effort, it is clear that there is still concern among teachers that this may not be an appropriate way to teach chemistry — this in spite of the fact that the world's largest chemical society produced ChemCom, and continues to support it enthusiastically as an appropriate introduction to chemistry for most students.
Figure 1.6  

Organization: ChemCom

- Curriculum Development
  - Teacher Feedback
  - Classroom Field Test

- Teacher Training
  - New Exam
  - Classroom Experience

Curriculum Emphases:
- Everyday coping
- Science, technology, and decisions
- Scientific skill development
(iii) Curriculum Development in Zimbabwe

In 1980, the Distance Science Teaching Unit (DiST) was established as a research project under the aegis of the University of Zimbabwe Research Board. The project was designed to bring hands-on science instruction, using low-cost, locally developed kits, into what were then upper primary classes staffed by science teachers who were ill-equipped to provide such instruction themselves. The kits were accompanied by a programmed, sequential study guide, and an audiocassette. The teacher introduced the lesson by playing the cassette; the students worked independently through the cued study guide, and answered text exercises. Then, the teacher/mentor reintroduced the cassette to "lead" the discussion and summarize the class activity. The individual student reached closure by completing a summary exercise or self-test (Dock, 1981).

Following independence, there was a dramatic increase in the secondary school population of Zimbabwe. In 1981 alone, there were some 1,100 new Secondary Form I classes created, while in existing urban schools it was possible to find as many as 18 Form I classes (Dock, 1981). The Ministry of Education and Culture recognized the importance of science education to the nation, but was hampered by a lack of trained manpower and financial resources. The DiST pilot-test had successfully demonstrated the feasibility of using programmed kits to teach science in a pupil-centered classroom. It was agreed at that time that the approach clearly held promise.

While the program was not expanded beyond the pilot, the system was adapted for use in Form I, as an integral component of what became a two-year course leading to the Junior Certificate in General Science. The adapted project, Zim-Sci, moved from the jurisdiction of the Science Education Center at the University to the Ministry of Education (see Figure 1.7). The initial charge was to develop a two-year course, within the existing syllabus, that would not place students taking this course at a disadvantage.

The syllabus itself was fairly traditional, emphasizing science as "correct explanations" and "science skill development." The DiST experience was modified by eliminating the use of the audiocassettes, thus giving teachers a greater role in pacing the lesson. The programmed pupil study guide remained, together with the kits (one kit per two pupils), with their carefully measured supplies and emphasis on using low cost, local materials. Specific behavioral objectives were included in the guide to help students monitor their own learning. The guide was written carefully to approximate the language style of the teacher.

The role of the teacher was viewed as that of (i) a lesson manager and organizer maintaining the pace of the lesson, and keeping the classroom under control, (ii) a discussion leader, and (iii) an evaluator of student achievement. A teacher's guide was provided to support the teacher in these roles. Teacher in-service support was also available.

Zim-Sci students performed well on the first national Junior Certificate examination (1982) compared to students from more traditional classes (Dock, 1984). Their subsequent examination results were acceptable; Zim-Sci is still taught in a number of lower secondary schools across Zimbabwe (Dock, 1991). However, in other schools Zim-Sci kits are on the shelf, or in need of repair.

Hungwe (1991), in his analysis of Zim-Sci, points out that low-cost equipment may result in short-term economies, but that the long-term picture may be another matter. If equipment is made from cheap materials it may require frequent repairs or replacement.

The third component of the Zimbabwe curriculum development experience is the O-level Core Science. (O-level, or Ordinary-level, standardized achievement examinations are a feature of school systems modelled on the British educational system. The syllabus is usually taught over a two-year period in grades 10/11.) Core Science was planned as a two-year follow-on to Zim-Sci with, however, a change in curriculum emphasis from the academic to the utilitarian. Core Science is applied science, designed to provide students with "everyday
Figure 1.7  Organization: DIST/ZimSci/Zimbabwe Core Science

University of Zimbabwe

DIST

ZimSci

Ministry of Education and Culture

Core Science

Cambridge Examinations Board
coping skills, through a strong component of technology education. It is an archetypical second-wave reform course, organizing its content around the themes of agriculture, industry, structures and mechanical systems, energy uses, and the community. It is designed for the 80% of students who will not be going on to take A-level science (a third year Extended Science syllabus was prepared for the 20% who would be taking science A-levels). (A-level, or Advanced-level examinations are taken after two years of specialist training in grades 12/13.)

A number of textbooks were written and, apart from a limited number of workshops, were all the support provided to the teachers. The Cambridge Local Examinations Board developed an examination for both Core and Extended Science that was first introduced in 1988. Almost 92,000 students took the Core examination, while over 12,000 sat the more traditional Extended Science.

Robson (1989) has effectively documented problems with the implementation of Core Science. Since the examination does not contain a practical, there is less incentive to do practical work. Also, overcrowding in the schools is making it logistically impossible for teachers to prepare and conduct practical activities; science kits, previously produced locally, are now being imported. In particular, teachers from the urban centers have resisted the course (which is compulsory), and teach their students toward passing the more traditional O-level course options. Thus, the intended curriculum and the implemented curriculum have very divergent goals. Teachers in rural schools recognize the value of Core Science, but doubt their own ability to teach it well. The attention of the Ministry (and the University) has moved on to other concerns.

As argued previously, a limiting determinant of successful second-wave reform is establishing the intellectual validity of science courses developed from the utilitarian tradition. Where there is a continuing oversight group to advocate, enforce, and nourish reform, it is difficult to accomplish, even in systems where the curriculum is enforced by a strong central authority. Where the stakeholders have, in effect, either dispersed or were never fully engaged in the first place, it may be impossible to establish a consensus that holds. For such a consensus the teachers need to understand more than just how to implement the course, they need to be convinced of its inherent value. Teachers also always need continued in-service education to support any new curriculum. Otherwise the intended and the implemented curricula will diverge, by either passive or active noncompliance.

(iv) Science For All Americans: Project 2061

This project is an ambitious attempt by the American Association for the Advancement of Science (AAAS) to define "the understandings and habits of mind [which] are essential for all citizens in a scientifically literate society." The project began in 1985 (when Halley's Comet paid its last visit to Earth). As implied by the name, this is a project that is taking the "long view." (Halley's Comet will not return until the year 2061 when it may be seen by children now starting in school.)

Phase I of the project was designed to establish the conceptual base for reform by delineating the knowledge, skills, and attitudes toward science that young people should have acquired by the time they complete U.S. secondary education (grade 12). This determination was made by panels of prestigious scientists, mathematicians, and engineers (AAAS, 1989). Teachers did not, as a group, contribute to the definition of what science is worth knowing, although individual teachers reviewed Phase I documents (see Figure 1.8).

Thus, the project began with its future prime curriculum emphasis already decided (no curriculum has yet been developed for this project). This is a project which arises out of the academic tradition, although other criteria were also used to define content. These were utility, social responsibility, philosophical value, and childhood enrichment.
Figure 1.8

Organization: Project 2061

(AAAS, 1989)

People

Individual scientists, engineers, and mathematicians

School system based educators and scientists

Other groups involved in science curriculum reform

Tasks

Phase I

Conceptual base for reform (knowledge, skills, attitudes)

Phase II

Development of curriculum models

Phase III

Strategies for implementing the reform

Curriculum Emphases:

Structure of science
Correct explanations
Self as explainer
The defined core covers many of the traditional topics found in most science courses. The term "science" is used not just to describe the physical and life sciences, but the behavioral sciences as well. Mathematics and technology are a significant component of the core. Also included are topics related to the interrelationships between science, mathematics, technology, and society; topics related to the nature of science; and, pivotal moments in the history of science. Traditional interdisciplinary barriers are blurred, and common themes across the sciences are emphasized. Most significantly, the developers have espoused the philosophy of "less [content] is more [knowledge]."

With regard to the "acceptability" of the defined science core, it represents a consensus of many distinguished scientists, mathematicians, and engineers. This was obviously a politically difficult task to accomplish. However, the core does not represent a consensus of the "establishment" of each discipline, as represented by the individual science societies. The reception of the excluded stakeholders to the Phase I reports has been somewhat ambiguous. This is in spite of the fact that many of these societies applaud the ambition of the project, and its ultimate intent.

Phase I involves the development of what are termed "curriculum models" by school-district based teams of educators and scientists based on the Phase I core. Several different models will be developed, perhaps with different secondary emphases, to serve as "blueprints" for the third stage of reform, which will be the actual production of curricula based on the Phase II blueprints. Phase II will also produce recommendations related to teacher training, examination structure, school organization, educational policies, educational research, and implementation strategies needed to accomplish the project's main goal of science literacy for all.

Phase III, which has not yet started, will involve collaboration with "scientific societies, educational organizations and institutions, and other groups involved in the reform of science, mathematics, and technology education in a nationwide effort to turn the Phase II blueprints into educational practice." Phase III implementation is expected to last 10 years.

The greatest weakness of Project 2061 would appear to be political, in that the first rule of curriculum reform (involve all the stakeholders in early decision-making) was clearly violated. This weakness may hinder successful implementation of Phase III.

The project's greatest strength is in its advocacy of the essential unity, and utility, of all science. Another great strength lies in the recognition that there is a need to reduce the content of existing science courses, an effort undertaken with much thought, and soul-searching, in Phase I. Ironically, but perhaps not surprisingly, given the complexity of much of the science content that appears to remain as "essential" knowledge for "all" Americans, Project 2061 may turn out to be a better redefinition of science for the future scientist than the future citizen.

Discussion

The mixed comments made on the four experiences do not mean that radical reform of the secondary science curriculum should not be attempted — either because it is too difficult, or because it does not deliver on promised outcomes. Quite the contrary. If science literacy is accepted as a legitimate national goal, however a nation chooses to define science literacy, the current academic curricula will have to be completely revamped. It is not sufficient to work on the more effective implementation of the defined curriculum, when the learning expectations embedded in that curriculum are totally unrealistic for the majority of students.
The four case studies presented illustrate several points. First, that curriculum reform is a process which takes place over a considerable period of time. Changing the curriculum is not as simple as adapting some other country's approach to science instruction by rewriting a previously published textbook. It requires an analysis of need, and a determination of how best to address this need.

Second, once a new approach has been selected and developed it must still be tested in the classroom, and rewritten as a result of classroom experience. The teacher must be allowed to contribute both to the initial formulation of the curriculum, and to its subsequent redesign. The initial teacher role appears to have been more integral to the development of the IPST curricula and ChemCom than to Zim-Sci or Phase I of Project 2061.

Third, whether or not curriculum reform is enforced by a central government authority or introduced as an option by a private organization, the teacher still determines what actually happens in the classroom. Paradoxically, it may be easier to implement curriculum reform in a decentralized system, simply because there is less compulsion to adopt a specific new approach in this type of system. Where there is choice, there is a need to "sell" a particular approach to the consumer -- the school authorities and the teachers. Hence, more attention may be paid to supporting the teacher in a decentralized system. The current, apparent success of ChemCom owes much to the availability of teacher training workshops. In contrast, the Core Science curriculum in Zimbabwe, although compulsory, is not implemented as intended because of teacher resistance. The lesson to be learned here is that curriculum reform cannot be imposed from above.

However, it is also true that radical reform of the science curriculum requires the blessing of the scientific community if it is to be accepted by the university establishment. When curriculum reform involves the cooperative efforts of both the science establishment and the grassroots (the teachers), successful implementation is much more likely.

Any kind of radical reform is risky, for success can never be guaranteed. Making no changes in either science content or teaching methods involves no risk, but will bring about no improvement in student achievement. When curriculum reform involves not just a shift in content, but a shift in pedagogy, then the risks are magnified -- but the possible gains are likely to be more substantial (see Figure 1.9). Both ChemCom and Project 2061 involve a content and pedagogical shift. While it appears that the former approach will meet its goals, it is much too early to predict the success of the latter.

An improvement in pedagogy without a change in basic content may result in gains in student performance in a fairly short period of time. This corresponds to the Zim-Sci experience, where the use of preprogrammed lessons based on science kits substituted for an improvement in teacher performance. However, if the students still do not perceive the relevance of classroom learning to their life outside the classroom, the apparent gains will be transient, especially if the teacher role is deemphasized.

Changing the content without changing the way in which the teacher delivers that content may, on novelty value alone, produce some student gains. For gains to continue, the teachers must improve their instructional skills. The ability of teachers to distort the intended curriculum, while usually not deliberate, should never be underestimated. There is NO teacher-proof curriculum as the fate of the Zimbabwe Core Science curriculum demonstrates.

The Thai curriculum is probably best characterized as a change in content, without introducing completely new pedagogy. Changes suggested by Soydhurum (1990a) to improve science achievement in Thailand focus on the curriculum, with an improvement in teaching performance implied but not delineated.
Figure 1.9

Risks Associated with Curriculum Change

<table>
<thead>
<tr>
<th>OLD PEDAGOGY</th>
<th>NEW PEDAGOGY</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLD CONTENT</td>
<td>NEW CONTENT</td>
</tr>
<tr>
<td>No change</td>
<td>Moderate risk, some learning gains</td>
</tr>
<tr>
<td>High risk, some learning gains</td>
<td>Greatest risk, most significant gains</td>
</tr>
</tbody>
</table>

One final point about science curriculum reform — it is a continuing process. A nation's educational priorities may shift, necessitating a redefinition of what content should be considered "essential"; a new generation of teachers may arise with better or, if possible, worse skills than their predecessors; a paradigm shift in our understanding of the workings of the natural world may render some of our current explanations obsolete; cognitive science may develop deeper insights into how young people learn science, etc.

Thus, the structure of a reform effort should contain feedback loops that not only permit revision of the original plan based on classroom experience, but, if necessary, the complete redesign of the project (see Figure 1.10). Curriculum reform should be viewed as a process involving successive approximations.
Figure 1.10

The Ongoing Nature of Reform

No learning from experience, no new design

DES → IMP

Learning from experience, no new design

DES

IMP

DES

IMP

DES

IMP

Learning from experience, new design for reform

DES = Design of reform

IMP = Implementation of reform
CHAPTER 2
LABORATORY INSTRUCTION

The Importance of Laboratory Instruction

The 1984 UNESCO survey on the place of science in the school curriculum included a question on the amount of time spent on practical activities ("hands-on" science, both "wet" and "dry" laboratory activities, not necessarily formal experiments). As shown in Table 2.1, which includes data from this survey supplemented from other sources, laboratory activities are reported as an integral component of secondary school science in countries around the world. The data presented in this table are not intended to be complete, but help illustrate the following points: (i) the percentage of science instruction time which is spent in the laboratory apparently ranges from 0% to 80%, and (ii) the percentage of science instruction time spent on practicals may increase or decrease as students move from lower secondary to upper secondary level science.

Both points need further explanation. The percentages reported for the countries listed may represent official expectations rather than actual classroom practice; they may be averages based on a wide, or narrow, range of possibilities; or they may even be based on guesswork. (Perhaps a more meaningful assessment of the significance given to laboratory-based instruction is whether or not it is examined.) An increase in time spent on laboratory work from the lower to upper secondary levels reflects a perception of the need to prepare students in the science stream for university science courses which focus on laboratory work. Since much science knowledge is acquired by observation, data collection, and controlled experiments, students in the science stream, as future scientists, need practice in these type of activities.

The decrease in practical work from lower to upper secondary level science is based on a completely different argument. It is explained that the older students "don't need" laboratory experiences in order to understand abstract concepts. The logic continues that while primary-level students need concrete experiences for effective learning in science, only lower ability older students may need such experiences (Haddad, 1986).

Both Walberg (1990) and Haddad (1986), in World Bank reports, have summarized much of the research related to the educational effectiveness of practical activities in science. They separately concluded that the research literature probably does not support claims made for the essential inclusion of a laboratory component to science programs. It is beyond the scope of this limited study to reexamine the body of research they have already carefully analyzed. It is true that, for a variety of reasons, claims for the potential value of the laboratory experience cannot be definitively substantiated.

It is also true that claims for the value of the laboratory experience in science cannot all be dismissed. A number of researchers have commented on problems with the experimental design of much of the research in this area, expressing particular concerns with the validity of the instruments used to determine the effectiveness of laboratory instruction (Hofstein, 1988; Hofstein and Lunetta, 1982; Tamir, 1972; Welch, 1971). Also, laboratory science has often been very badly taught at all levels (including at university) in most countries, developed and developing — thus it is not valid to dismiss its possible impact when taught well.

What exactly is the function of laboratory instruction? The rationale for school-based practical science has shifted over the years, depending on the emphasis of the curriculum (see Chapter 1). When science is taught emphasizing "correct explanations" or a "solid foundation," the claim is that practical activities make it easier for students to understand, and retain, the facts and concepts of science. When science is taught as "scientific skill development" or the "self as explainer," then the laboratory is considered a means of giving students insight into
the ways in which scientists think, the ways in which scientific knowledge accumulates. It is also argued that the excitement and creativity of science can be conveyed to students through laboratory activities. Table 2.2 presents one view of the many goals of laboratory activity.

**TABLE 2.1**

**Percentage Time for Practical Activities in Secondary Science**

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liberia</td>
<td>1 hour/week</td>
</tr>
<tr>
<td>Cameroons (Eng.)</td>
<td>1 hour/week (grades 10-12); 3 hours/week (grades 13/14)</td>
</tr>
<tr>
<td>Malawi</td>
<td>4:1 (practical:theory)</td>
</tr>
<tr>
<td>Nigeria</td>
<td>17% teachers report labs &quot;great deal of time&quot;; 37% report labs &quot;fair amount&quot;</td>
</tr>
<tr>
<td>Tanzania</td>
<td>8:3 (practical:theory)</td>
</tr>
<tr>
<td>Iran</td>
<td>labs &quot;available&quot; 20% of time</td>
</tr>
<tr>
<td>Oman</td>
<td>50% (grades 10-12)</td>
</tr>
<tr>
<td>U.Arab E.</td>
<td>30%-50% (grades 10-12)</td>
</tr>
<tr>
<td>Australia</td>
<td>50% (grades 11/12)</td>
</tr>
<tr>
<td>China</td>
<td>14% (grades 7-9)</td>
</tr>
<tr>
<td>India</td>
<td>30%-35% (grades 9/10)</td>
</tr>
<tr>
<td>Japan</td>
<td>20%-21% (grades 7-9); 8%-22% (grades 10-12/13)</td>
</tr>
<tr>
<td>Lao PDR</td>
<td>8%-13% (secondary science)</td>
</tr>
<tr>
<td>Philippines</td>
<td>9%-21% (grades 7-10)</td>
</tr>
<tr>
<td>Malaysia</td>
<td>50% (grades 10-11)</td>
</tr>
<tr>
<td>Thailand</td>
<td>25%-75% (35% teachers report 50% time in lab)</td>
</tr>
<tr>
<td>New Zealand</td>
<td>33% (secondary science)</td>
</tr>
<tr>
<td>Bolivia</td>
<td>21% (secondary science)</td>
</tr>
<tr>
<td>Guyana</td>
<td>40% (secondary science)</td>
</tr>
<tr>
<td>Jamaica</td>
<td>25% (secondary science)</td>
</tr>
<tr>
<td>Uruguay</td>
<td>25%-30% (secondary science)</td>
</tr>
<tr>
<td>Hungary</td>
<td>30% (secondary science)</td>
</tr>
<tr>
<td>Sweden</td>
<td>20% (physics); 25% (chemistry); 30% (biology)</td>
</tr>
<tr>
<td>USA</td>
<td>6%-50% (grades 9-12)</td>
</tr>
<tr>
<td>USSR</td>
<td>16% (physics); 24% (chemistry); 20% (biology)</td>
</tr>
</tbody>
</table>
TABLE 2.2

Goals of Laboratory Activity
(In Hofstein, 1988)

<table>
<thead>
<tr>
<th>DOMAIN</th>
<th>GOAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive</td>
<td>Promote intellectual development</td>
</tr>
<tr>
<td></td>
<td>Enhance the learning of scientific concepts</td>
</tr>
<tr>
<td></td>
<td>Develop problem-solving skills</td>
</tr>
<tr>
<td></td>
<td>Develop creative thinking</td>
</tr>
<tr>
<td></td>
<td>Increase understanding of science and scientific method</td>
</tr>
<tr>
<td>Practical</td>
<td>Develop skills in performing science investigations</td>
</tr>
<tr>
<td></td>
<td>Develop skills in analyzing investigative data</td>
</tr>
<tr>
<td></td>
<td>Develop skills in communication</td>
</tr>
<tr>
<td></td>
<td>Develop skills in working with others</td>
</tr>
<tr>
<td>Affective</td>
<td>Enhance attitudes toward science</td>
</tr>
<tr>
<td></td>
<td>Promote positive perceptions on one's ability to understand, and to affect</td>
</tr>
<tr>
<td></td>
<td>one's environment</td>
</tr>
</tbody>
</table>

It would be unrealistic to expect any one laboratory activity, however well-designed, to address all of these goals in a 45-minute exploration. In the real world of the classroom, the multiple goals of specific laboratory activities have not been clear in the teacher's mind, let alone shared with the students. There has been a tendency for science educators to act as if "hands-on" science, in and of itself, will result in all desired learning outcomes. As many have pointed out, it is necessary to couple "hands-on" with "minds-on," if the laboratory is to lead to productive learning (Gardner, 1990). It is also important to find ways to assess exactly what is the "learning bonus" when students take science courses that include well-designed, well-taught laboratory activities (see APU studies in the UK).

The "science for all" movement changes some of the issues regarding the essential nature of the laboratory. Haddad (1986) accepted that there is a decreasing need for practical work as a student enters the Piagetian stage of formal operations. He recognized the "relatively high percentages of high school and college students [who] are judged to be still at the concrete operational stage," but hypothesized "that the proportion of such students is much smaller in countries where only a very small selected proportion of an age group are enrolled in schools and colleges." This "selected proportion" is increasing in most countries; as science becomes mandatory for this larger group of students, the need to provide concrete experiences to facilitate an understanding of the abstract must surely become greater, not less. This is one reason why there is a very urgent need to determine the best ways to incorporate hands-on/minds-on science into "science for all" courses.

In developing countries, there are two additional, closely linked reasons why "hands-on" science may be essential to an understanding of science concepts (rather than an ability to retain science by rote memory and, hence, pass examinations). The scientific concepts that a student is expected to master may be completely counter to the cultural "worldview" which the student brings to the learning process (Okebukola and Jegede, 1990; Vlaardingerbroek, 1990; Hewson, 1988; George and Glasgow, 1989). Where such concepts are both counter culture and counter intuitive, there may be a special need to attach concept formation to concrete reality — even if this has not been well done in the past (a supposition in line with constructivist thinking).

The language barrier in science teaching is also relevant to this discussion (Eisemon, 1991; Cleghorn, Merritt, and Abagi, 1989; Lynch, Chipman, and Pachaury, 1985). In developing countries, many students are
being taught science in a second language, or in a language which has no words to describe particular scientific concepts. The needed words are then "translated" into the native tongue, sometimes with imprecision. Learning in science has a strong language component anyway, with the introduction of new "vocabulary" in some courses exceeding the rate of introduction in foreign language lessons. There is also enough of a problem with the disparate meanings of certain words in, say, everyday English and scientific English to make scientific vocabulary a barrier to effective learning among native speakers of English (see, for example, the work of Johnstone at the University of Glasgow). Again, the laboratory experience, if carefully constructed, taught, and measured, may prove to be essential to full understanding.

With regard to the student who is in the stage of formal operations, even those students who can reason formally do not do so all the time. Also, it should never be forgotten that science remains an experimental approach to knowledge acquisition. This knowledge may not necessarily be acquired through the traditional laboratory or field experience (the computer, for example, may be used for much scientific modelling today), but the need to know how to "do" science is necessary for students who intend to become scientists. The sooner this is an integral part of their education, the better, since "those who learn a subject well when younger are likely to continue learning later" (Walberg, 1990).

While much of the above discussion has assumed the special value of laboratory-based instruction for the concrete thinker, this may be an extremely simplistic way of analyzing the situation. There is some evidence that the laboratory experience is more highly valued by the brighter students (Lewin, 1981). There is also evidence that many scientists became scientists precisely because of their enjoyment of laboratory activities.

In the United States, an analysis of Advanced Placement (AP) Chemistry examination results has shown that, no matter how long or short the time spent on chemistry instruction, the highest grades are associated with those students who spend a greater percentage of their instructional time in the laboratory (Taft, 1988). (The Advanced Placement examinations, developed by the Educational Testing Service, give U.S. high school students an opportunity to obtain college-level credit for a course taken in high school, usually in 12th grade.)

The Educational Testing Service has also determined that there is a significant discrepancy between the amount of time AP students spend in the laboratory (45 minutes/week or less), and the time spent by general chemistry students in college (113 minutes/week to 368 minutes/week) (Taft, 1990). Since passing this examination with high grades is supposed to permit U.S. high school students to skip general chemistry in college, these findings are very disturbing. The Educational Testing Service is encouraging high schools to increase their current laboratory offerings for AP Chemistry. While this data applies to one set of examinations in one advantaged country, it may have much wider implications. The interface between upper secondary and college science instruction is turbulent in many countries, but in most countries upper secondary laboratory work is expected to prepare students for college work.

Finally, Gardner's (1990) comments on laboratory-based chemistry may have relevance to other sciences:

"It has been noted that one difference between the professional chemist and the novice is that the professional routinely creates mental pictures of molecular-scale systems and events. George Pimentel [prominent American research chemist and chemical educator] once observed that a chemist sees one thing and thinks another. When student minds are actively involved at the laboratory bench, they learn how to form such 'pictures in the mind,' thus allowing them to add a sense of order and rationality to their activities and observations, and suggesting reasons for the changes noted. Such a 'minds on' approach gives students the opportunity to grow intellectually and to increase their problem solving and critical thinking skills."
Laboratory Assessment

That which is not tested is not taught; that which is not well-tested is not well-taught. The problem of deciding exactly which learning outcomes result from laboratory activity, and how best to measure them is a major issue. Despite this problem, a number of countries do include practical assessment as a component of their standardized examinations (see Table 2.3 for examples).

**TABLE 2.3**

The Role of the Practicals in External Assessment

(Holbrook, 1991)

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>STANDARDIZED EXAMS AND PRACTICAL ASSESSMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lesotho</td>
<td>No practical assessment</td>
</tr>
<tr>
<td>Swaziland</td>
<td>No practical assessment</td>
</tr>
<tr>
<td>Zambia</td>
<td>Project work discontinued as unreliable</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>Practicals assessed, not considered valid</td>
</tr>
<tr>
<td>India</td>
<td>Practicals assessed through projects, teachers</td>
</tr>
<tr>
<td>Pakistan</td>
<td>Practicals assessed (25%), graded by teachers</td>
</tr>
<tr>
<td>Philippines</td>
<td>Teacher assessment includes practicals, projects</td>
</tr>
<tr>
<td>Barbados</td>
<td>Practicals assessed by teacher</td>
</tr>
<tr>
<td>Trinidad</td>
<td>Practicals assessed by teacher (also attitudes, class work), 20-30% of external exam, considered valid and reliable</td>
</tr>
<tr>
<td>PNG</td>
<td>Practicals and projects collectively must not exceed 20% of the internal assessment component (50%) of the school-leaving examinations</td>
</tr>
<tr>
<td>UK</td>
<td>GCSE not less than 20% of total marks for &quot;experimental and other practical skills&quot; of which at least half are lab-based.</td>
</tr>
</tbody>
</table>

In the United Kingdom, the introduction of the General Certificate of Secondary Education (GCSE) has reaffirmed the importance of laboratory instruction in science (Secondary Examinations Council, 1986). The teacher's guide for GCSE science states:

* The assessment of coursework by teachers can provide the best evidence of candidate's achievement in certain process areas of science. So, for example, coursework assessment may be far more effective than timed, written papers where candidates are expected to show:

1. Research skills: including the ability to select, organize and evaluate information from a wide range of sources.
2. The ability to design, conduct and report on investigations of various kinds.
3. The ability to review, evaluate and adapt methods of enquiry over a period of time.
4. The ability to make and record accurate observations in the laboratory or field.

5. Motor skills: including the safe manipulation of apparatus and handling of materials.

Since the GCSE was only introduced for the first time in 1988, problems associated with the continuous assessment of practical work are still being solved. The various examinations boards have interpreted the national criteria in different ways, resulting in some confusion. Welford (1990) has suggested that while the examination boards may not have defined "laboratory skills" in sufficient enough detail to result in a technically valid assessment, they may have provided more detail than can be practically handled by teachers in the classroom.

There have been a number of attempts, especially in the United Kingdom, to produce a valid and reliable practical test (the Assessment of Performance Unit, APU, science surveys; the Techniques for the Assessment of Practical Skills in Science Project; Warwick Process Science, the Graded Assessment in Science Project.) Such efforts have also been undertaken in Canada, and in the Netherlands. Doubts still persist about the reliability of practical assessment as with many other forms of assessment but there is research evidence that practicals do test some other component of knowledge than written tests (see, for example, the results of the APU science surveys).

A number of ways of assessing laboratory-related skills have been proposed. Table 2.4 lists some of these methods, together with the advantages and disadvantages associated with each method.

Laboratory Instruction in Developing Countries

Under the best of conditions with well-prepared teachers, laboratory instruction is problematic. In developing countries where there may be many unqualified science teachers, especially at the lower secondary level (see Chapter 3), there are more problems to consider. In many schools, there may not be a laboratory; equipment may be non-existent or in disrepair; there may be no electricity or running water in the schools, especially in rural areas; and, there may be no system in place to resupply consumable materials — or no money. As described in Chapter 5 (q.v.), the bulk of World Bank loans for secondary school science have supported the construction and equipping of laboratory facilities. Given the costs of building and equipping the traditional school science laboratories (see next section), and the uncertain benefits of laboratory instruction, especially as delivered by unqualified teachers under unsatisfactory conditions, much more attention needs to be paid to these kind of expenditures (see also Chapter 5).

Under what physical conditions is it appropriate to conduct hands-on science? At the lower secondary level, a modern hands-on science course can be successfully implemented in much simpler surroundings than is generally assumed — a large set-aside room, with sinks and running water, acid-resistant table tops, a source of electric current, locked storage space, and plenty of horizontal surfaces for display purposes etc. are probably all that are needed. Spirit burners may be used instead of gas. One non-negotiable (although frequently ignored) component of any laboratory, especially where chemicals are used, is construction for safety, and safety equipment. However, if hands-on chemistry is conducted at the microscale (as defined later in this chapter), it is probably safe to eliminate fume hoods. (Information on the range of laboratory techniques now designated as microscale, or small-scale chemistry, needs to be much more widely available than at present. This is one instructional trend from the United States which should be very useful to all countries concerned with cost and safety.)
Laboratories at the pre-university level do need to be more sophisticated in design — but, again, probably not as much as is assumed. Unfortunately, possession of a "sophisticated" school laboratory is not only a status symbol, but its design can be based on memories of laboratory experiences of years gone by. Note that reconceptualizing the laboratory experience in any country involves changing both the syllabus and the standardized examinations.

**TABLE 2.4**

**Laboratory Assessment**

(Gardner, 1990; Giddings and Fraser, 1988; Alberts et al., 1986)

<table>
<thead>
<tr>
<th>METHOD</th>
<th>ADVANTAGE</th>
<th>DISADVANTAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practical</td>
<td>1. lab techniques can be evaluated</td>
<td>1. takes time</td>
</tr>
<tr>
<td>(structured, time-limited, hands-on)</td>
<td>2. can assess higher order thinking</td>
<td>2. cost</td>
</tr>
<tr>
<td></td>
<td>3. emphasis on nature of science</td>
<td>3. need for individual equipment</td>
</tr>
<tr>
<td></td>
<td>4. manipulative skills can be assessed</td>
<td>4. control factor for large classes</td>
</tr>
<tr>
<td>Lab-based written exercise</td>
<td>1. no lab needed</td>
<td>1. techniques not assessed</td>
</tr>
<tr>
<td></td>
<td>2. length/complexity can be varied</td>
<td>2. good test design a challenge</td>
</tr>
<tr>
<td></td>
<td>3. can cover many types of activity in one test</td>
<td></td>
</tr>
<tr>
<td>Performance checks*</td>
<td>1. assesses work in progress</td>
<td>1. takes time</td>
</tr>
<tr>
<td>Teacher demonstrations</td>
<td>1. less time/cost than practicals</td>
<td>2. cannot be rechecked for accuracy</td>
</tr>
<tr>
<td></td>
<td>2. uses equipment and techniques</td>
<td>1. no assess of student manual skills</td>
</tr>
<tr>
<td>Laboratory journals</td>
<td>1. like research notes of working scientists</td>
<td>1. bulky</td>
</tr>
<tr>
<td></td>
<td>2. on-the-spot record of lab as data produced</td>
<td>2. time-consuming to grade</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. quick teacher feedback needed</td>
</tr>
<tr>
<td>Open continuing research</td>
<td>1. may involve teamwork as &quot;real&quot; science</td>
<td>1. team-work results in some student non-participation</td>
</tr>
<tr>
<td></td>
<td>2. motivates students</td>
<td></td>
</tr>
<tr>
<td>Laboratory reports</td>
<td>1. requires attention to all aspects of lab</td>
<td>1. take time to produce and grade</td>
</tr>
<tr>
<td></td>
<td>2. teaches importance of keeping full records</td>
<td>2. tends to be subjective</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. students may copy</td>
</tr>
</tbody>
</table>

*Continuous assessment such as following instructions, selecting correct equipment, handling materials correctly, making accurate measurements, recording data accurately, correct calculations, etc.

The equipment and consumables with which laboratories are furnished also need to be carefully considered. It is obvious from the World Bank's experience in supporting loans to purchase laboratory equipment that there is a need for an informed appraisal of all equipment ordered. Equipment that is "too sophisticated" for teachers to use, or repair, is useless (see Chapter 5).

Equipment used in school laboratories, especially at the upper secondary and tertiary levels, is expensive; it often has to be imported to developing countries. Instruments may be difficult to maintain in good repair, and spare-parts for repair may not be readily available; equipment may even be delivered already broken. In the
schools, the teachers may be held accountable for all broken equipment, so there may be a real disincentive to use even the limited equipment that is available.

An alternative to the importation of expensive equipment, which may remain on the shelf, is the production of low-cost, locally made equipment, either by teachers and students in workshops, or at local production centers. There may even be learning advantages in using low-cost equipment. The equipment is often "transparent," i.e., it is simple enough in construction for students to understand how it works, and for teachers (and students) to repair if broken (Tobón, 1988).

One concern related to the use of such equipment is the sense that it "isn't good enough" to produce acceptable quantitative results and, therefore, produces inferior learning. There is also a pride factor involved, as typified by the comment, "We want our students to use real equipment." These concerns must be addressed. Some locally made equipment is of poor quality, and likely to fall apart easily. When teachers are not taught how to maintain equipment this is a particular problem — not just in the case of locally made equipment, but for equipment from any source.

However, much (although not all) of the equipment now being produced locally is quite sufficiently accurate for the skills of the students, and the purposes of instruction, as well as being of sturdy construction. Most countries have to explore some way to reduce the costs of teaching the experimental sciences (Thulstrup, 1988; Thulstrup and Waddington, 1983). This is true for all sciences at all levels of instruction. All countries are potential purchasers of low-cost equipment. One example from the United States is the "Bottle Biology" (i.e., biology experiments in used two-liter soda bottles) project of the University of Wisconsin at Madison. Here is an attempt to work with "no cost" equipment, necessary for many U.S. high schools. Schmidt (1990) has run very successful workshops for teachers in Ethiopia, Ghana, and Tanzania also attempting the "no cost" approach to laboratory instruction. It is not suggested that teachers in developing countries have the time, or experience, to be able to construct much of their own equipment from locally available materials — all that is implied is that teachers need to be taught to use the local environment, and natural phenomena, as part of "hands-on" science.

Locally produced equipment may not be low cost; in some instances it may be cheaper to import equipment from abroad. If this is the case, then there still remains the issue of who will maintain this equipment. One rationale for producing laboratory equipment locally must surely be the accompanying availability of trained technicians for maintenance. Another is the opportunity to provide maintenance workshops to teachers. (Other issues related to the logistics of equipment procurement and distribution are discussed in Chapter 5 on the Bank's experience.)

The design of low-cost, "programmed" kits has been advocated as one way to work with (i.e., around) unqualified teachers (see Zim-Sci discussion in Chapter 1). Just as there are no teacher-proof curricula, there are no teacher-proof kits — not even the very best! There is even some evidence that using kits to work around teachers tends to lower their morale (Hungwe, 1991). It is always true that the introduction of new equipment, low or high cost, "programmed" or otherwise, should be accompanied by teacher inservice workshops.

There have been some very interesting approaches to equipment design and manufacture utilizing teachers. For example, in 1986 in the Phillipines, the then Science Promotion Institute of the National Science and Technology Authority held a competition among secondary school science teachers to improvise science equipment for use in biology, chemistry, physics, and general science classes (Science Education Institute, 1986). The Institute has also run workshops on the development of low-cost equipment for college physics (Science Education Institute, 1988).
Educational equipment production centers are found in more than 40 countries including India (National Council of Educational Research and Training – NCERT); Thailand (Institute for the Promotion of Teaching Science and Technology – IPST); Kenya (Science Equipment Production Unit – SEPU); Nigeria (Science Equipment Center); Brazil (Fundação Brasileira para o Desenvolvimento do Ensino de Ciencias – FUNBEC); and Venezuela (Centro Nacional para el Mejoramiento de la Ensenanza de la Ciencia – CENAMEC). Key factors which contribute to the success of an equipment production center include: structured management; well-trained technicians; professional designs; quality control; cooperation between centers, teachers and curriculum developers; effective marketing and distribution; and production of multi-purpose equipment to permit large production runs (and, hence, low per unit production costs) (Morris, 1990; Steward, 1983; Seng, 1983).

Accurate figures on the extent to which school science equipment is produced locally on a worldwide basis are not easy to come by. Figure 2.1 illustrates the extent to which science equipment is produced locally for Asia and the Pacific. This includes equipment that may not be low cost, just produced in-country.

Cost Considerations

The International Institute for Educational Planning survey mentioned previously collected data on the costs of laboratory construction, and equipment and materials purchase in 11 developing countries (Caillods and Göttelmann-Duret, 1991). These data are summarized in Table 2.5. The costs of constructing laboratory facilities vary considerably from country to country, since the base cost quoted may, in some cases, include only construction and fittings and not the fixed furniture. There are also a range of costs possible within a country, with rural schools costing significantly more than urban schools in both Kenya and Botswana, especially if constructed with funds from a bilateral aid agency. According to the Institute study, constructing a school laboratory in a rural area in Kenya is 900 times more expensive if supported by foreign aid than by an association of parents.

Generally, laboratories in lower secondary schools are less expensive than in upper secondary schools because the former tend to be simpler. This is not, however, the situation in Senegal, where costs are higher for lower secondary schools. Laboratories in the science schools of Korea are more than twice as expensive as laboratories in Korean lower secondary schools.

The equipment costs cited were extremely high for most countries. Typically, biology equipment was more expensive than chemistry and physics, and costs were higher at the upper secondary level than at the lower. All of the countries surveyed imported all or most of the equipment used. It was reported that a fully installed and equipped physics laboratory in Botswana, Burkina Faso, Kenya, Morocco, Senegal, and Papua New Guinea costs from 117 to 145 times the per capita GNP. For Thailand and Korea this figure is 30 times the per capita GNP, in Jordan 19 times, and in Chile seven times.

Given these costs, and the unproven benefits of laboratory instruction, it is not surprising that many are questioning the role of the secondary school laboratory. The low-cost equipment option certainly needs to be revisited. The literature on low-cost equipment tends to focus on how to make individual pieces of equipment, and how accurate specific examples of low-cost instruments can be. It tends not to be explicit on cost considerations, except perhaps on an individual piece of equipment basis. Depending on the piece of equipment, and the country involved, savings may range from 100% (the so-called "no-cost option") to about 20% (see, for example, Thulstrup and Waddington, 1983). Given the time limitations of this particular study, it was not possible to conduct a multi-national survey to collect data comparing the costs of "traditional" vs. "low-cost" equipment on a country-by-country basis. This study is needed.
Figure 2.1

Percentage of Science Equipment Produced Locally, Asia

Key

CPR = China (Rep.)
IND = India
IRA = Iran
JPN = Japan
LAO = Laos
MAL = Malaysia
MDV = Maldives
NZE = New Zealand
NEP = Nepal
PAK = Pakistan
PHI = Philippines
PNG = Papua New Guinea
ROK = Republic of Korea
SIN = Singapore
SRL = Sri Lanka
THA = Thailand
TUR = Turkey
VIE = Vietnam

Source: UNESCO, 1984
The following four examples illustrate that it is possible to produce, and successfully use, low-cost science equipment. They are: (i) the design and manufacture of microelectronics-based equipment for chemistry and physics instruction, initially at the University of Delhi, but now world-wide; (ii) the production of science kits for home use and to support curriculum innovation in Brazil; (iii) the teacher- or commercial-production of prototype equipment at the Regional Center for Education in Science and Mathematics in Malaysia; and, (iv) the microscale chemistry movement in the United States.

**TABLE 2.5**

The Cost of Science Laboratories: Construction and Equipment
(Caillods and Göttelmann-Duret, 1991)

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>CONSTRUCTION AND FIXED FURNISHINGS</th>
<th>DESCRIPTION</th>
<th>EQUIPMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>COST (USS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>$85,660</td>
<td>A center consisting of physics room, chemistry room, natural sciences room, practical workshop; fully installed w. prep room, fixed furnishings</td>
<td>$6,700</td>
</tr>
<tr>
<td></td>
<td>(8.6)</td>
<td></td>
<td>100% imported</td>
</tr>
<tr>
<td>Senegal</td>
<td>$113,000</td>
<td>A science and technology unit of 2 multi-purpose rooms, and 4 storage rooms; fully installed w. prep room</td>
<td>Nat. sci. $14,000</td>
</tr>
<tr>
<td></td>
<td>(8.1)</td>
<td></td>
<td>Phys. sci. $14,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Technol. $8,400</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Econ. $8,400</td>
</tr>
<tr>
<td>Kenya</td>
<td>See description</td>
<td>Capital --- rural --- remote</td>
<td>$9,400</td>
</tr>
<tr>
<td></td>
<td>(40-20-10)</td>
<td>High: $32,000 — $64,000 — $80,000</td>
<td>100% imported</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Need: $20,000 — $32,000 — $40,000</td>
<td>Kits @ $600</td>
</tr>
<tr>
<td>Botswana</td>
<td>$51,500 (1.16)</td>
<td>Junior science room</td>
<td>Integ. sci. $7,900</td>
</tr>
<tr>
<td></td>
<td>$17,200 (0.39)</td>
<td>Junior secondary prep room</td>
<td>Physics $12,120</td>
</tr>
<tr>
<td></td>
<td>$24,100 (0.48)</td>
<td>Senior secondary prep room</td>
<td>Chemistry $12,380</td>
</tr>
<tr>
<td></td>
<td>$107,800 (1.28)</td>
<td>Physics, chem, or biology lab</td>
<td>Biology $13,800</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Installed w. prep room, fixed furnishings</td>
<td>100% imported</td>
</tr>
<tr>
<td>Morocco</td>
<td>$50,000-56,250 (3.3-4)</td>
<td>Science unit of 2 special rooms, prep room, fully installed Fixed furnishings</td>
<td>Lower secondary:</td>
</tr>
<tr>
<td></td>
<td>$1,090</td>
<td></td>
<td>Nat. sci. $41,528</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Phys/chem $22,351</td>
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<td></td>
<td></td>
<td>Upper secondary:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nat. sci. $71,566</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Phys/chem $93,723</td>
</tr>
<tr>
<td>Jordan</td>
<td>$14,400-18,000 (1.6-2)</td>
<td>Includes prep room, 3 labs for chemistry, physics, biology</td>
<td>For 3 labs total of $31,500,</td>
</tr>
<tr>
<td>PNG</td>
<td>$76,500 (2)</td>
<td>Multi-purpose, lower sec., installed w. prep room  Physics, chemistry, biology lab.</td>
<td>$18,000-22,500</td>
</tr>
<tr>
<td></td>
<td>$90,000-99,000 (2.6)</td>
<td></td>
<td>Kits biol. $3,600</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>chem. $3,420</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>phys. $2,250</td>
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<tr>
<td></td>
<td></td>
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<td>earth sci. $1,530</td>
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</tbody>
</table>

Figures in bold face and parentheses express the costs of the laboratory as a multiple of the cost of a general education class. For example, (2) means that the laboratory cost twice the cost of a general classroom.
### TABLE 2.5 (continued)

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>CONSTRUCTION AND FIXED FURNISHINGS</th>
<th>EQUIPMENT</th>
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<tbody>
<tr>
<td></td>
<td>COST (US$)</td>
<td>DESCRIPTION</td>
</tr>
<tr>
<td>Thailand</td>
<td>Regular school: $19,440-$24,300</td>
<td>Chem lab furnishings $4,160; biology $3,980; physics $3,980; sciences $3,980; prep room $1,568</td>
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<tr>
<td></td>
<td>Community sch.: $10,368</td>
<td>Prep room $3,456; science furnishings $3,824; prep room $994</td>
</tr>
<tr>
<td>Korea</td>
<td>$29,100 (2)</td>
<td>Size of 67 sq. meters, w. prep room</td>
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<td></td>
<td>$43,500 (2.1)</td>
<td>Size of 101 sq. meters, w. prep room</td>
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<tr>
<td></td>
<td>$57,800 (2.1)</td>
<td>Size of 135 sq. meters, w. prep room</td>
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<tr>
<td>Chile</td>
<td>$13,000 (L.3)</td>
<td>Multi-purpose lab, installed, fixed furnishings</td>
</tr>
<tr>
<td>Argentina</td>
<td>$450-500/sq. m $35,000</td>
<td>For 70 sq. meters</td>
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</table>

Figures in bold face and parentheses express the costs of the laboratory as a multiple of the cost of a general education class. For example, (2) means that the laboratory cost twice the cost of a general classroom.

(i) India: the Edutronics Experience

In 1989, the then Vice Chancellor of the University of Delhi presented the Vice Chancellor of Indira Gandhi National University with 900 pieces of low-cost equipment, developed by the Edutronics Group at Delhi for a little over one-sixth of the cost of commercial equipment of comparable quality. Ten years previously, the Chemistry Department of the University of Delhi had begun a pilot project to design, develop, test, and refine chemistry teaching instruments for use in tertiary-level laboratory instruction (Sane and West, 1991a). The objectives of the project were:

- to develop reliable low-cost locally produced equipment that is easy to fabricate and easy to maintain;
- to find experiments compatible with the equipment that illustrate the principles and practice of modern chemistry;
to transfer the know-how to teachers through hands-on workshops, manuals and videotapes;

- to set up a production unit which can supply kits and assembled equipment without a significant escalation of cost; and,

- to encourage curriculum changes that ensure that the whole package enables a student to be better trained for a career in chemistry.

Twelve years later, with support from numerous international organizations, but especially from the International Union of Pure and Applied Chemistry-Committee on Teaching of Chemistry (IUPAC-CTC), the International Council of Scientific Unions-Committee on Teaching of Science (ICSU-CTS), and UNESCO, this program is the hub of an international network that includes chemistry and physics educators from Brazil, Australia, Denmark, Germany, France, Jordan, the Philippines, Puerto Rico, Thailand, and Yugoslavia (Sane and West, 1991a).

In addition to these active centers, workshops on the production and use of a variety of instruments have been held in Guyana, Bangladesh, Sri Lanka, Singapore, Pakistan, Nepal, Malaysia, Afghanistan, Hong Kong, and Mauritius. Since 1981, in India alone there have been 19 teacher training workshops involving some 500 teachers primarily from colleges and universities, although Indian secondary school teachers have also attended these workshops (Sane and West, 1991a, b). While the equipment developed was designed with the early years of university instruction in mind, much of it has been used for chemistry and physics instruction at the upper secondary level.

The equipment developed by the Edutronics Group includes analog, digital, and meterless production models of pH meters, conductance meters, and colorimeters. There are demonstration models for single wavelength atomic absorption spectrophotometers, and for flame photometers. Prototype versions of numerous other analytical instruments have been explored, with design work still to be completed.

The group has also designed a no-cost carbon electrode (from discarded batteries), a magnetic stirrer, a timer, a thermostat, a minicentrifuge, and an instrument test package. Tested experiments using this equipment cover classic chemistry, as well as explorations in biochemistry and agricultural, environmental, clinical, and industrial chemistry.

The work of the Edutronics Group is supported by the Indian University Grants Commission through a program to provide teacher training, equipment packages, and a set of investigations to all colleges in India. Currently, much of the fully tested equipment is built in sheltered workshops, supported by the Department of Science and Technology.

(ii) Brazil: From Kits to Curriculum

In the 1950s, a concern for the quality of science instruction in the primary and secondary schools of Brazil led to a group of university professors designing and producing a series of science kits for student home use. The project (which had evolved into FUNBEC by 1967) went through a series of modifications, resulting in the development of "mini-kits" containing equipment and materials to perform experiments on a limited topic (e.g., mirrors, circuits, plant growth, chromatography, calories in food, etc.). These kits were designed primarily for lower secondary school students (11-15 years), although there were also kits for upper secondary students, and 9-11 year-olds (Raw, 1983).
This project attracted the attention of a commercial book publisher, leading to the production of a series of science kits based on the history of science, which were packaged to look like books, and were sold on newspaper stands throughout Brazil. About 200,000 of the first units were sold, with sales dropping off as the market saturated. This activity also evolved into another product — medium-sized science kits also sold on newspaper stands and in toy stores.

The public attention generated by these out-of-school kits led to political attention — educational authorities “realized that they could actually equip laboratories within their limited budgets” (Raw, 1983). (Actual budget data is not now readily available.) The initial excitement of the 1960s science education reform movement coincided with the developing expertise of these intrepid university entrepreneurs. FUNBEC (and other small companies) began to provide school systems with the equipment and instructional materials they needed to implement curriculum reform. Six regional centers were established to provide in-service courses to teachers, most associated with local universities. By 1979, FUNBEC was producing about $3 million of school equipment per year, with actual production depending on the availability of public funds.

Later, FUNBEC expanded its production facilities in Sao Paulo to support the development of university and research equipment. The Foundation developed a thriving medical electronics division, supplying cardiology equipment to medical schools and hospitals all over Brazil. From an operation in a two-car garage, emphasizing simple technology and no production engineering, FUNBEC developed into a thriving, modern, university-based industrial plant.

(iii) Malaysia: The Regional Center for Education in Science and Mathematics

RECSAM was initially established in 1967 to help members of the South-East Asian Ministers of Education Organization (SEAMEO) improve the teaching of science and mathematics in their respective countries. The Center is financially supported by member and associate member countries, international donor agencies, and various donor governments. RECSAM serves as both a teacher training and development center (see Chapter 3), an information clearinghouse, and a materials and equipment design facility.

As shown in Figure 2.2, equipment ideas developed in RECSAM workshops go through a series of steps before they result in equipment for the classroom (Seng, 1983). This begins with a feasibility study to determine whether or not the materials, tools, and skills are available to produce the equipment. Designs are developed, constructed, and tested leading to a workshop prototype of the equipment for classroom testing. After testing, the educational prototype can be manufactured either on a small scale by teachers or laboratory technicians or, following an encouraging cost analysis, mass produced by factories or cottage industries.

Prototype equipment is kept on display at the Center's facility in Penang, and publicized via technical reports and newsletters. Workshops on production and use of this equipment have been offered since 1972. Courses are typically 10 weeks in length, and include the teaching of construction skills, and technical drawing. Participants design a piece of equipment, develop and produce its technical specifications, and then actually make the equipment. The writing of a final report is considered most important, since RECSAM is in the business of exporting ideas across the region. When participants return to their own communities they may conduct “cascade” workshops for other teachers; serve in a consultant capacity on equipment-related issues; supervise employees in other equipment centers; design additional equipment; contribute to the equipment development component of curriculum reform; or conduct research into ways to produce other types of equipment (Seng, 1983).
Figure 2.2

Equipment Production

- EQUIPMENT IDEA
  - FEASIBILITY STUDY
  - BEST DESIGN
  - WORKSHOP CONSTRUCTION
    - WORKSHOP TESTING
    - WORKSHOP PROTOTYPE
      - FIELD TESTING

- EDUCATIONAL PROTOTYPE
  - COST-EFFECTIVE STUDY
    - SMALL-SCALE PRODUCTION
      - TEACHER PRODUCTION
      - LABORATORY STAFF PRODUCTION

- PROTOTYPE REFINING
  - INDUSTRIAL PROTOTYPE
    - COST-EFFECTIVE STUDY
      - MASS PRODUCTION
        - FACTORY PRODUCTION
        - COTTAGE INDUSTRY PRODUCTION

- EQUIPMENT IN SCHOOL
  - DISTRIBUTION

Source: UNESCO, 1983
The United States: Microscale (Small-scale) Chemistry

Microscale chemistry experiments have been conducted in organic chemistry laboratories, at both the tertiary and upper secondary levels, for a number of years. Recently, there has been a renewal of interest in organic microscale, a downsizing of the amounts of chemicals handled in a microscale laboratory, and the adoption of microscale chemistry equipment and techniques in general chemistry, again at both the tertiary and secondary levels. This movement is viewed as the beginning of a major shift in the way in which chemistry laboratory instruction will be delivered in the United States. (In "microscale" experiments, students use milligram quantities of chemicals and simplified equipment designed to handle these small quantities. To distinguish the new microscale from the old, IUPAC-CTC has proposed the term "small-scale" chemistry.)

The movement toward microscale chemistry began initially as an attempt to reduce student and teacher exposure to hazardous chemicals, and to minimize production of federally regulated waste materials. Concerns for legal liability, and the costs of waste disposal were paramount. As teachers in schools and universities became more familiar with the types of equipment used in microscale, and as "traditional" experiments were modified for the new techniques, it became clear that there are many other advantages to this approach (Wood, 1990; Zipp, 1989):

- Microscale experiments can be safely conducted in any room in a building. There is no need for a laboratory equipped with all modern safety devices in order to teach microscale.
- Microscale experiments can even be conducted in lecture halls containing in excess of 100 students. A large class size becomes less of an issue.
- Microscale experiments tend to take less time, so students can complete more than one activity in a 50-minute time frame.
- Students must work with greater dexterity and accuracy when handling small amounts of materials, thus improving their manipulative skills.
- Fewer chemicals are consumed, so teachers spend less time in solution preparation. Less space is needed for chemicals storage.
- Microscale is safer, so some experiments previously abandoned for safety reasons can return to the classroom.
- A microscale laboratory is significantly cheaper to operate than the traditional laboratory. One reason for this is that less chemicals are consumed; another is that microscale equipment is apparently more durable than traditional glassware. Most general chemistry experiments do not even require any glassware, but use inexpensive plastic pipets and well plates.

The previous point needs additional explanation. There is an initial outlay for microscale equipment that might not be otherwise purchased. The cost of maintaining this equipment, and resupplying needed chemicals, has been estimated at about one-tenth of the cost of a traditional general chemistry laboratory. Zipp (1989) reported Mayo's calculation that even including the cost of completely reequipping an organic laboratory, the cost-savings in maintenance results in payback of the original investment in six years.
In the United States, the use of microscale chemistry equipment and techniques is considered an extremely significant development. Even an institution such as the U.S. Air Force Academy, which certainly can afford other approaches, uses microscale chemistry equipment and techniques in its general chemistry laboratory program (Much, 1991).

Discussion

There are many unanswered questions regarding the most appropriate role of laboratory activities in secondary science instruction, especially given the high costs involved. There is clearly a need for much more research into exactly what is being learned through laboratory instruction; how this knowledge differs from science information acquired through the lecture; and how it can be measured reliably. These are all important issues. Until the value of laboratory-based instruction is definitively established, it will continue to come under attack from those who do not understand its integral importance to an understanding of science. There is also a danger that if practicals can not be reliably tested then they will disappear, first from the examination and then the classroom.

The arguments for and against laboratory-based instruction have tended to focus on the Piagetian framework of concrete versus formal operations. Given the experimental nature of scientific inquiry, and the motivational impact of laboratory work on the future scientist, the contribution of the laboratory to learning in science is a lot more complex than "just" illustrating the abstract.

It may now be necessary to redesign the traditional activities performed in school laboratories — or even to reconceptualize the content of laboratory instruction completely. In the United States, the introduction of small-scale chemistry is clearly associated with a reevaluation of the importance of many "classical" chemistry experiments. As the focus of the curriculum moves away from science in the laboratory to science in the community, the laboratory activities of value in science instruction should also shift, especially at the lower secondary level. The development of manipulative skills, and an ability to perform accurate measurements using simple equipment, are competencies transferable to adult life (science, and technology, for all).

At the upper secondary level, a facility in using instruments and techniques that are obsolete in the working world of science would appear to have little pedagogical value for either future citizens or future scientists. However, giving all students an opportunity to ask their own scientific questions, and design experiments using fairly simple equipment to answer these questions, does have value. The content of laboratory instruction for students in pre-university specialist courses must be revised in conjunction with university departments to ensure that students enter university prepared for the modern laboratory experience.

Attempts to completely eliminate laboratory instruction in secondary schools should be strongly rejected. Requests to support the teaching of laboratory-based sciences as they were taught 20 years ago should also be rejected. At present, the use of low-cost equipment, where feasible locally produced, must always be considered if both costs and pedagogy are to be taken into account. The Edutronics Group at the University of Delhi has demonstrated that it is possible to produce fairly sophisticated electronic equipment of a sufficient degree of precision to be used even in university instruction, at a relatively modest cost. There are many other successful models for production of such equipment in the developing world — it is both a tested, and an acceptable, solution (c.f., RECSAM and FUNBEC). A multi-national survey to collect data comparing the costs of "traditional" vs. "low-cost" equipment on a country-by-country basis could very persuasive in accelerating the acceptance of this approach. This survey would also need to demonstrate that science instruction using such equipment was not, in any way, "second class."
There remain the issues of teacher comfort with laboratory instruction, teacher familiarity with modern instrumentation, and the capability of teachers to maintain equipment, or improvise from local materials. Teachers need more support than they are currently receiving in order to integrate meaningful, student-centered, laboratory-based activities into an intellectually coherent, modern science program. Unless teachers are better prepared to teach "hands on/minds on" science, laboratory instruction will continue to be attacked as an expensive waste of time.
CHAPTER 3

THE TEACHERS

The Importance of the Science Teacher

While there is some ambiguity about the relationship between teacher academic background and student achievement in developed countries, teacher qualifications do appear to be more closely related to student achievement in the developing world (Haddad, 1985). The qualifications of science teachers seem to be especially related to student achievement in science. In an earlier review for the World Bank, Husen, et al. (1978) showed that the educational background of primary and early secondary science teachers (and teachers of mathematics and literature) had a positive impact on student achievement. Husen also recognized the positive impact of higher-qualified science teachers on upper secondary students in Malaysia, India, the Philippines, and several Latin American countries. A comparative analysis of student achievement in the First International Science Assessment showed that, after verbal ability, for 14-year-old students from India and Chile the most significant determinants of student achievement were teaching methods and teaching qualifications—which together had approximately the same impact on achievement as all other school variables (Noonan, 1977).

These findings are consistent with the U.S. study by Bonstetter, et al. (1983) comparing teachers in exemplary science programs with other teachers. In this study it was determined that while 52% of a national sample of all secondary science teachers (N = 1121) had a degree beyond the bachelor's level, 76% of teachers in designated "exemplary" science programs (N = 102) were so qualified. Some 68% of the latter group had taken an advanced degree with a science concentration. More than 80% of exemplary U.S. science teachers had completed more science courses than is required for most U.S. undergraduate science degrees; 47% had taken a college course for credit within the past two years. Of special note is that these exemplary teachers indicated that their main sources of inspiration included: other teachers (83%); journals and other professional publications (71%); college courses (60%); involvement in special projects (51%); and meetings of professional organizations (50%). The degree of collegiality and professionalism in the group is striking—and suggestive.

The Qualifications of Teachers

It is difficult to find quantitative data related to the educational background of science teachers in more than a few developing countries. Only a few of the country reports from the Second International Study of Science have been released, while the summary report has not yet been published. Also, only a few developing countries participated in this study (see Chapter 4). Even qualitative data tends to be fragmented, confusing, and perhaps out-of-date. Differences among educational systems also make it very difficult to compare teacher qualifications from country to country.

However, a number of generalizations are possible. In most countries entry into some form of secondary science teacher education takes place after 12 years of previous education, although 10 and 11 years are also common. In most systems, though not all, secondary school science teachers are expected to have taken courses in both science content and pedagogy, typically through a four-year program. This translates into a number of differently titled qualifications, emphasizing either the science or the education component of the training.

For example, a well-qualified science teacher in anglophone Africa might have an undergraduate degree in science from a university (a three- or four-year course of study), together with a teaching certificate or diploma (an additional one year of training including practice teaching). A teacher with this type of qualification is more likely teach at the upper secondary level. At the lower secondary level, the teacher may not be required
to have a science degree but may be expected to have a teaching diploma from a teacher's training college (two or three years). Entry into the university program is usually after 12 years of secondary education. Entry into the teacher's training college follows either 10 or 12 years of schooling.

In reality, science teachers in many Sub-Saharan countries may have only an O-level science background (c.f., Chapter 1) with or without some teaching courses (e.g., Uganda, Zambia, Zimbabwe). Another possibility is that the teachers have a science degree with no teacher training background. Table 3.1 suggests the range of possibilities for the countries listed. The table is not complete; it is not quantitative; but it is indicative.

Table 3.2 provides recent quantitative data for Nigeria collected as part of a nation-wide survey of the resources for science, mathematics, and technology education in Nigerian secondary schools, completed in 1985, but containing a good deal of data compiled in 1983 (Yoloye, 1989). Column 1 teachers have less than the HND (Higher National Diploma), or the NCE (National Certificate in Education, a three-year teacher training program after six years of secondary education), and have taken no teaching courses. Teachers in Column 2 also have less than the HND or NCE, but they have received some teacher training. Teachers in Columns 3 and 4 have the HND, either with or without a teaching qualification. The teachers represented by Column 5 have the NCE or equivalent qualification. (NCE teachers are not supposed to teach at the upper secondary level, although many do.)

The final two rows give the percentage of teachers with an undergraduate science degree in each listed discipline, which may or may not be in that discipline — there is a good deal of teaching out of field. Column 6 teachers have no teaching diploma with their degree; Column 7 teachers have a degree and a teaching diploma. Aggregating these categories, 21% of physics teachers, 19% of chemistry teachers, and 18% of biology teachers are considered unqualified. For the other disciplines listed, the comparable numbers of unqualified teachers are: agricultural science (41%), health science (18%), and mathematics (33%).

Another survey in Nigeria, conducted in 1989 for the World Bank (Ivowi, 1991), examined a smaller sample of science teachers (in four schools in four states). Of 84 teachers responding to the survey (44% return), 26 (31%) had an undergraduate degree and teaching qualifications; 29 (35%) had the professional NCE qualification; and 24 (29%) had a science degree with no teaching qualifications. There can be many reasons for the different profile: the selection of the sample; the likelihood that the better qualified teachers answered the survey; or even an improvement in teacher qualifications over the past five or six years. The second survey does provide additional evidence of teachers teaching out-of-field, and of NCE teachers teaching at the upper secondary level.

In francophone Africa, entry into teacher education follows success in either the Baccalauréat or an institute-specific entrance examination. For example, in both Tunisia and Algeria secondary science teachers may either complete a four-year course of study at an Ecole Normale Superieure or they are recruited straight from university without pedagogical instruction. In both countries there is a strong emphasis on the science component of the preparation. In Morocco, reportedly 97% of science teachers are considered qualified (Caillods and Göttemann-Duret, 1991). For lower secondary school teachers this means at least two years of post-secondary education at a regional pedagogical center; for upper secondary teachers this is at least four years at a teacher's college.

Caillods and Göttemann-Duret also reported that 100% of science teachers in Burkina Faso, 89% of Senegalese science teachers, and 61% of Kenyan science teachers met their countries differing minimal qualifications (Caillods and Göttemann-Duret, 1991). For lower secondary teachers in Burkina Faso and Senegal this is either two years of post-secondary education at a teacher's college, or two years of science
### TABLE 3.1
*Qualifications of Secondary Science Teachers, Selected Countries in Africa*  
(Bregman, 1991; Zymelman, 1990; Collison, 1984)

<table>
<thead>
<tr>
<th>COUNTRY/GRADES</th>
<th>SS CERT</th>
<th>TT CERT</th>
<th>COL DIP</th>
<th>UNIVERSITY DEGREE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ethiopia</strong></td>
<td>7/8 9-12</td>
<td>*</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td><strong>Ghana</strong></td>
<td>7-10 11-13</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>Kenya</strong></td>
<td>9-13</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>Malawi</strong></td>
<td>9/10 11/12</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>Mali</strong></td>
<td>7-9 10-12</td>
<td>*</td>
<td>*</td>
<td>?</td>
</tr>
<tr>
<td><strong>Nigeria</strong></td>
<td>7-9 10-12</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>Senegal</strong></td>
<td>7-10 11-13</td>
<td>*</td>
<td>*</td>
<td>?</td>
</tr>
<tr>
<td><strong>Tanzania</strong></td>
<td>8-11 12/13</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>Uganda</strong></td>
<td>8-11 12/13</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>Zambia</strong></td>
<td>8/9 10-12</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>Algeria</strong></td>
<td>7-9 10-12</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>Morocco</strong></td>
<td>7-9 10-12</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>Tunisia</strong></td>
<td>7-9 10-12</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

**Key:**  
- SS CERT - a secondary school-leaving certificate with no other training  
- TT CERT - a certificate or diploma in teaching plus a 10th or 12th grade leaving certificate, but less than a college diploma  
- COL DIP - a college diploma for teaching, beyond the TT CERT but less than a degree  
- ED - undergraduate degree in education (BEd), or a first degree awarded by a faculty of education  
- SC - a first undergraduate degree in science (BS/BSc), from a faculty of science  
- SC+T - BS degree plus a one-year teacher training diploma or certificate  
- SC+ED - either a double degree in science/education, or a degree from the faculties of science/education.

* This table does NOT describe the desired/legally required qualifications in these countries, nor is it intended to be complete.
TABLE 3.2
Qualifications of Secondary School Teachers in Nigeria
(Yoloye, 1989)

<table>
<thead>
<tr>
<th>SUBJECT</th>
<th>QUALIFICATIONS (AS %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;HND/NC E N O T</td>
</tr>
<tr>
<td>Physics</td>
<td>12.8</td>
</tr>
<tr>
<td>Chemistry</td>
<td>11.0</td>
</tr>
<tr>
<td>Biology</td>
<td>8.8</td>
</tr>
<tr>
<td>Agri. Sci.</td>
<td>16.1</td>
</tr>
<tr>
<td>Health Sci.</td>
<td>7.7</td>
</tr>
<tr>
<td>Mathematics</td>
<td>13.9</td>
</tr>
</tbody>
</table>

Key: HND - Higher National Diploma; NCE - National Certificate in Education; T - Teacher training; EQ - Equivalent; GRAD - Graduate with a bachelor's degree (see also text)

Instruction at university, followed by one year of pedagogy. For upper secondary school teachers in Burkina Faso and Senegal this is three to four years at a faculty of science, with one year of pedagogical training. In Kenya, the minimal qualification for science teachers is three years at a post-secondary teacher training college.

The situation in Latin America is a little different (see Table 3.3). Here, science teachers may have a "licenciado" in science education (a four- or five-year program of study after 11 or 12 years of schooling), awarded by either the university faculty of education or the faculty of science. Another possibility is a joint degree in science and education (again a four- or five-year program) awarded jointly by the faculties of education and science. (There seems to be some communication between education and science faculties in many Latin American countries, but how smoothly this communication proceeds can only be surmised.) In some countries in Latin America (e.g., Brazil, Equador, Mexico), secondary science teachers may have qualifications in engineering, medicine, or law. Science graduate students may also work part-time as science teachers (e.g., Guatemala, Mexico).

In Latin America, as in other parts of the world, there is a good deal of teaching out-of-field, particularly in physics. In Brazil, where three years of physics is compulsory for all secondary students, it is estimated that 40% of the physics teachers do not have a licenciado in physics (Rodriguez, et al., 1989). Physics is taught by mathematics, biology, and chemistry teachers. The qualifications of physics teachers in Costa Rica are shown in Table 3.4.
### TABLE 3.3

*Qualifications of Secondary Science Teachers, Selected Countries in Latin America and the Caribbean*  
(Rodriguez, et al., 1989)

<table>
<thead>
<tr>
<th>Country</th>
<th>SS CERT</th>
<th>TI CERT</th>
<th>UNIVERSITY DEGREE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SC</td>
<td>ED</td>
<td>SC</td>
</tr>
<tr>
<td>Argentina</td>
<td>8-12</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Brazil</td>
<td>9-11/12</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Chile</td>
<td>5-9-12/13</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Columbia</td>
<td>6-9</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Costa Rica</td>
<td>7-9</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Equador</td>
<td>7-9</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Guatemala</td>
<td>7-9</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Jamaica</td>
<td>7-9</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Mexico</td>
<td>7-9</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Venezuela</td>
<td>8/9</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

Key:  
- SS CERT - a secondary school-leaving certificate with no additional training;  
- TI CERT - a certificate or diploma from a tertiary level institute, that is not equivalent to a first degree;  
- ED - undergraduate degree in education (BEd), or a first degree in science education awarded by a faculty of education;  
- SC - a first undergraduate degree in science (BS/BS) awarded by a faculty of science;  
- SC+T - BS degree plus a one-year teacher training diploma;  
- SC+ED - either a double degree in science and education or a joint degree from the faculties of science and education;  
- OTHER - Other undergraduate degree, often engineering in Latin America.

*This table does NOT describe the desired/legally required qualifications in the countries, nor is it a complete description of the situation in these countries.*
TABLE 3.4

Qualifications of Physics Teachers in Costa Rica
(Rodriguez, et al., 1989)

<table>
<thead>
<tr>
<th>Survey</th>
<th>Degree: secondary teaching</th>
<th>Degree: primary teaching</th>
<th>Degree: science education</th>
<th>Degree: other subjects</th>
<th>Degree: physics</th>
<th>No degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey 1</td>
<td>40%</td>
<td>10%</td>
<td>24%</td>
<td>18%</td>
<td>1%</td>
<td>7%</td>
</tr>
<tr>
<td>Survey 2</td>
<td></td>
<td></td>
<td>65%</td>
<td>10%</td>
<td>14%*</td>
<td>6%</td>
</tr>
</tbody>
</table>

Survey 1 is a 50% response to a nationwide survey sent to all Costa Rican schools offering physics. Survey 2 is of the densely populated central region. For survey 1, a degree in "other subjects" means chemistry, biology, engineering, or business administration. For survey 2, the degree in "other subjects" means mathematics. *For survey 2, the category of physics degree also includes chemistry and biology.

The two surveys illustrate a world-wide phenomenon—the prevalence of the preferred qualification (in this case the degree in science education) in the more urban areas.

While there are certainly science teachers in Latin America with a poor preparation in science, particularly in the rural secondary schools where the teachers may only have been trained as primary school teachers, there is also perceived to be a problem with teachers who have a reasonably good understanding of science, but no teaching qualifications (Rodriguez, et al., 1989; Gallagher, 1986). Even those teachers who have received teacher training have had little exposure to teaching methods courses. However, there may be little institutional support for the introduction of new teaching methods in many countries in Latin America (Rodriguez, et al., 1989).

Secondary science teachers in Asia, as elsewhere, typically have a range of backgrounds in both science and pedagogy (see Table 3.5). This may be a four-year science degree plus a year of teacher education (e.g., India, Malaysia, Pakistan, Singapore); a joint science/education degree from a university (e.g., China, Republic of Korea, Malaysia); a university degree in education with a specialization in science (e.g., Philippines, Thailand); or a science education diploma from a teacher’s training college (e.g., Sri Lanka, Thailand). As in other parts of the world, teachers at the upper secondary level are more likely to have a science degree than teachers at the lower secondary level.

There are also a few programs at the master’s degree level in science education for upper secondary teachers (e.g., India, Pakistan). In India, there is a concern that one year of teacher education following a science degree is not sufficient. Hence, the National Council of Educational Research and Training (NCERT) has run experimental four-year integrated, interdisciplinary courses leading to a B.Sc.Ed. at its four Regional Colleges of Education. At the less qualified end of the spectrum, again at the lower secondary level, science teachers may have a 10th-grade school education followed by teacher training of varying lengths up to several years. A higher secondary school certificate in the sciences with no teacher-training courses (e.g., Bangladesh, Nepal).

In Hong Kong, at the lower secondary level 53% of science teachers have a university degree, and 68% have a teaching certificate or diploma (Holbrook, 1990a). At secondary-level 6, 97% of biology...
### TABLE 3.5

*Qualifications of Secondary Science Teachers.*
**Selected Countries in Asia**
*(UNESCO, 1985; UNESCO, 1984)*

<table>
<thead>
<tr>
<th>COUNTRY/GRADUES</th>
<th>SS CERT</th>
<th>TI CERT</th>
<th>UNIVERSITY DEGREE</th>
<th>OTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iran</td>
<td>9-12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>India</td>
<td>9/10</td>
<td>11/12</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Indonesia</td>
<td>7-9</td>
<td>10-12</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Malaysia</td>
<td>7-9</td>
<td>10/11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nepal</td>
<td>6/7</td>
<td>8-10</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Pakistan</td>
<td>9/10</td>
<td>11/12</td>
<td>*</td>
<td>MS/T</td>
</tr>
<tr>
<td>Phillipines</td>
<td>7/8</td>
<td>9/10</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Singapore</td>
<td>7-10</td>
<td>11-12</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>7-10</td>
<td>11-12/13</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Thailand</td>
<td>7-12</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

Key: SS CERT - a secondary school-leaving certificate with no additional training; TI CERT - a certificate or diploma from a tertiary level institute (often called a college) that is not equivalent to a first undergraduate degree; ED - an undergraduate degree in education (BED) or a first undergraduate degree from a faculty of education; SC - a first undergraduate degree in science (BS/BSc) awarded by a faculty of science; SC+T - BS degree plus a one-year teacher-training diploma or certificate; SC+ED - either a double degree in science and education, or a joint degree from the faculties of science and education; OTH - Other, Pakistan reports that a master's degree in science with teacher training is needed for the pre-university group (however a BS in Pakistan is obtained after 14 years of education).

*This table does NOT describe the desired/legally required qualifications for each of these countries, nor is it a complete description of the situation.*
teachers, 98% of chemistry teachers, and 97% of physics teachers have a university degree (Holbrook, 1990b). At secondary 7, the figures are 99% for biology, 98% for chemistry, and 100% for physics. About 50% of these teachers have 100% of their degree in science. Some 80% (secondary 6) and 86% (secondary 7) of biology teachers have a teaching diploma; 77% (S6) and 87% (S7) of chemistry teachers; and 62% (S6) and 79% (S7) of physics teachers.

The educational qualifications of Philippine biology teachers in 1986/87 were as follows: 31% had either a bachelor of science (BS) or a bachelor of science education (BSE) in biology; 23% had a BSE in general science (Thulstrup, 1990). Of the chemistry teachers, 21% had a BS or BSE in biology, and 15% had a major in chemistry. Of the physics teachers, only 4% had a BS or BSE in physics; 31% had a mathematics major, and 18% a background in general science.

Figure 3.1 shows the percentage of science teachers with the desired qualifications for 10 Asian countries (UNESCO, 1984). This figure illustrates a situation that is found all over the world, not just in Asia. There is a greater percentage of "qualified" science teachers at the upper secondary level than at the lower, with the percentage of "qualified" science teachers at the primary school level being the lowest of all. The term "qualified," of course, has a different definition at each level, and varies from country to country.

It should be made quite clear that qualifications with the same title in different countries do NOT necessarily represent the same level of educational accomplishment. In some systems a bachelor's degree can be obtained after a total of 14 years of education (e.g., Pakistan), in other countries it may take a total of 17 years to earn an undergraduate degree (e.g., many countries in Latin America). What may be termed a "degree" in one country may be the intellectual equivalent of a "diploma" or a "certificate" in another. However, in all countries the term "degree" does imply a higher status than a diploma. It should also be noted that comparisons across systems can only be approximate.

A degree in education can describe a very wide range of course content, not just from country-to-country but from institution-to-institution within the same country. The ratio of science courses to education courses varies widely—in one program the balance may be about 80% science to 20% education; in another, the balance may be 20% science to 80% education. A 50/50 split in content is also possible.

Figure 3.2 shows the course emphasis in Venezuela for education degrees in general science and physics. Both are four-year programs. The science component is taught as a body of knowledge; the epistemology content illustrates how this knowledge is constructed. The "educational technology" component of instruction includes teaching methods and strategies based on modern learning theory and the "needs of society" (de Bascones, 1988). This general science program would be followed by a future lower secondary school teacher.

The incredible range of training at this level is further illustrated by the following examples. In Algeria, secondary teacher trainees at an Ecole Normale Superieure will begin with one year of course work in a few related subjects (e.g., mathematics, physical sciences). In the second and third years the trainees specialize in one subject, and in the final year they take pedagogical courses and practice teaching. The program is similar in Tunisia except that the pedagogical courses start in the third year (World Bank documents).

In Thailand, the four-year B.Ed. program for a secondary science teacher consists of about 40% course work in the science major, 12% courses in the minor, 21% general foundation courses in science and mathematics, and 27% professional teaching courses (Soydhurum, 1990a). The BSE (bachelor of education with a science major) degree in the Philippines is also a four-year program, but follows only 10 years of schooling not 12 years as in Thailand.
Figure 3.1
Percentage of Teachers With Desired Qualifications, Asia

Key

<table>
<thead>
<tr>
<th>Level</th>
<th>Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Secondary</td>
<td>JPN CPR.ROK SIN MAL</td>
</tr>
<tr>
<td>Lower Secondary</td>
<td>JPN MAL</td>
</tr>
<tr>
<td>Primary Level</td>
<td>JPN MAL</td>
</tr>
</tbody>
</table>

Source: UNESCO, 1984
Figure 3.2
Teacher Education in Venezuela

General Science Teachers
- General science: 35%
- Epistemology: 5%
- Sociology: 10%
- Psychology: 15%

Physics Teachers
- Physics: 60%
- Ed. tech: 10%
- Epistemology: 10%
- Sociology: 10%
- Psychology: 10%

Source: de Bascones, 1988
Courses are taken in communication arts, general psychology, performing arts, social science, education, and the sciences. This is a 156 credit program of which 30 credits are taken in the major area of specialization. There is a 10-week on-campus practicum in the fourth year, followed by 10 weeks in off-campus schools (UNESCO, 1985).

In the Punjab, where it is unusual for lower secondary level teachers to specialize, teacher training involves taking 10 or so subjects over a 39-week period, followed by six to seven weeks of practice teaching (World Bank documents). Of these subjects, the following are compulsory: child psychology, school and community development, principles of education, counselling, testing and evaluation, school organization and preparation of teaching aids, social studies, and Islamait. This leaves two courses to be selected from mathematics, science, arts and crafts, Urdu, English, and home economics.

Despite the great variety, a four-year post-secondary program of some kind seems most common. In 1984, educators from Bangladesh, China, India, Malaysia, Nepal, Pakistan, the Philippines, the Republic of Korea, and Sri Lanka met to review teacher training in each others' countries, and to design model teacher education programs (UNESCO, 1985). They agreed that secondary science teacher preservice education should include both subject matter content (50%), professional education courses (35%), and courses to round out a liberal education such as social science, language instruction, and mathematics. Their proposed four-year curriculum is given in Table 3.6 as one model, not necessarily the ideal. Students from these countries may have had 10, 11, or 12 years of compulsory schooling before entering this kind of program. Presumably the depth of the science content covered will differ significantly from country to country, depending on both the number of years in school, and the depth of specialization before entering the program.

Training the Teacher Trainers

Science teachers around the world tend to teach science through lectures, allowing little time for class discussion, outside speakers, etc. It is a truism that teachers teach the way they were taught and not the way they were taught to teach. Unfortunately, the teacher educators also teach the way they were taught. The type of instruction teachers receive during teacher education, whether preservice, inservice, or onservice, becomes the limiting determinant of how the teachers will behave in the classroom. If they are taught solely via lectures, with no opportunities to ask questions, then they are likely to teach that way. If they are taught through laboratory experiences, they will value the laboratory in their own teaching. If they are taught in an authoritarian fashion, then they will find it very difficult to move to the student-centered classroom that is a feature of so many of the second wave "science for all" courses, and is associated with enhanced student learning. Hence, if teachers are to change their classroom practices significantly, they should first be taught by instructors who have already changed their teaching styles.

Unfortunately, in too many countries, the teacher educators receive no instruction on how to teach themselves (Mayer, 1990). They may be former secondary school teachers who have been promoted out of the classroom because they are effective teachers. There is no guarantee that they can transmit their own talents to others; they often can not find the time to keep up with the latest developments in their science specialty, or in science education research.

Over the past 10 to 15 years, a vast body of scholarly research in science education, especially in the area of cognitive psychology, has resulted in a much greater understanding of how science concepts are understood by the students, and how teachers can facilitate this understanding by the ways in which they present material. The "expert" teacher promoted to teacher educator is often not familiar with this research, and usually needs additional instruction before being able to present it to future teachers.
TABLE 3.6
Recommended Program of Study for Secondary Science Teachers
(After UNESCO, 1985)

<table>
<thead>
<tr>
<th>AREAS</th>
<th>TIME</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science content</td>
<td>50%</td>
<td>Science as a human activity; includes environmental topics; selection depends on major</td>
</tr>
<tr>
<td>History &amp; philosophy of science</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science, technology, &amp; society</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science concepts &amp; principles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laboratory work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Professional education</td>
<td>35%</td>
<td></td>
</tr>
<tr>
<td>Psychology of learning science</td>
<td>25%</td>
<td>To include recent developments; for skills &amp; rational thinking; includes the computer</td>
</tr>
<tr>
<td>Science content &amp; teaching methods</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laboratory techniques</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Educational technology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaluation in science education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curriculum &amp; instruction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science education research</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student teaching/internship</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foundations/other education courses</td>
<td>10%</td>
<td>Made relevant to teaching and learning</td>
</tr>
<tr>
<td>Liberal education</td>
<td>15%</td>
<td>Humanities, communications</td>
</tr>
</tbody>
</table>

Other possibilities are that the teacher educators have an appropriate science background, but little understanding of educational theory, or a strong background in educational theory but a poor preparation in science (UNESCO, 1985). For example, in Asian countries, the teacher educators tend to have a bachelor's degree in either science or science education, and a master's degree in science or education; they typically have not received an education relevant to their instructional responsibilities (UNESCO, 1985). Another example, in Nigeria many of the instructors are not familiar with continuous assessment techniques, methods of remediation, and large-group teaching practice. Hence, the students do not learn these teaching strategies.

There is also the issue of tertiary-level instructors as "experts" on secondary-level science teaching, when they may never have taught below the university or college level. This is also a problem in Nigeria, where most of the teacher educators will have a first degree or equivalent, but have limited experience in science and mathematics instruction at the secondary level. Also, most will have no experience in teaching integrated science, now compulsory at the lower secondary level in Nigeria.

New methodologies in biology teacher education have been introduced in a number of teacher training colleges throughout anglophone and francophone Africa. This is true in Sierra Leone at Njala University College; in Kenya at the Kenya Science Teachers College; in Egypt at Ain Shams University; in Nigeria at Ibadan University and Jabba Teachers College, and at teacher training colleges in Senegal and Mali. The new programs tend to take an environmental, ecological approach to biology instruction. Teachers are also learning techniques of continuous assessment, and how to evaluate the affective component in biology learning (Rugumayo, 1989).
The desired preparation for science teacher educators was discussed at a meeting held in Bangkok in 1985 attended by science educators from Bangladesh, China, India, Malaysia, Nepal, Pakistan, the Philippines, Korea, and Sri Lanka. The participants advocated a graduate-level program consisting of science content (35%), science education including science education research (35%), foundations of education (10%), and electives in the first three areas (20%). They recommended an entry-level science requirement for this proposed program of at least a bachelor’s or master’s degree in one science discipline. They also strongly made the point (relevant now and everywhere) that increased collaboration between faculties of science and education is necessary to ensure the competence of future science teacher educators (UNESCO, 1985). Too often this lack of cooperation makes it virtually impossible for students to connect the pedagogical theory they are introduced to by one set of lecturers, with the subject matter knowledge they are taught by another. This is not to suggest that student teachers must be taught science content in a completely different fashion from future scientists or engineers (although there are arguments in favor of this approach), but that science methods courses be delivered by instructors who know how to integrate knowledge in the two realms.

The development of graduate programs in science education for future teacher educators is a relatively new phenomenon in developing countries. In 1984, Seoul National University started a science education doctoral program. The Korean program takes a minimum of three years and has a course balance of 50% science to 30% science education. Two research theses are required, one in science, the other in science education (UNESCO, 1985). Pakistan has also implemented a program, with support from the Asian Development Bank (1985), to provide international fellowships to “master” science teachers for graduate-level study in science education.

The International Union of Biological Sciences—Commission for Biological Education (IUBS-CBE) is concerned enough about the preparation of biology teacher educators worldwide that they are planning to develop a set of guidelines to define an intellectually acceptable program for future biology teacher educators (Mayer, 1990). Mayer has suggested that any framework developed should be flexible enough to accommodate the following types of programs:

- a one-year, full- or part-time program for new teacher educators, as a condition for permanent appointment;
- an on-the-job development program for all inadequately qualified teachers;
- an one-year post-graduate diploma in teacher education;
- a master’s degree in teacher education.

There appears to be a very real need to develop such guidelines for all the sciences not just biology. The need for well-prepared science teacher educators becomes even more urgent when a new curriculum is to be introduced, especially if the new curriculum can be characterized as second-wave reform. As previously discussed, a change in both pedagogy and content are characteristic of the second-wave science courses. Thus, improving the educational background of the teacher educators must be considered essential to any meaningful reform of science education in the developing world.

Continuing Education

Continuing education opportunities are necessary so that: (i) unqualified secondary science teachers can become at least minimally qualified to teach; and, (ii) qualified teachers can stay abreast of new knowledge in science and pedagogy. In reality, in many developing countries there is such a need to improve the educational
background of the unprepared science teacher that the need for regular inservice education is either not satisfied, or not even recognized. In other countries, regular inservice education may be required in order to maintain status as a qualified teacher, to receive a pay raise, or to ascend a career ladder.

Inservice education can take many forms. Table 3.7 summarizes the possibilities for India, where a range of programs are available through universities, colleges, and national and regional science centers. One rather different series of workshops developed by the State Institute of Educational Research and Training (SIERT) in Rajasthan trains teachers in the use of a science club kit designed to assist in preparing students for project work (for science fairs and exhibitions). SIERT has also offered workshops on improvising low-cost equipment, and has trained over 300 laboratory assistants over a seven-year period (Morris, 1990).

Similar types of programs are available in a number of Asian countries. For example, in the Republic of Korea primary and secondary school teachers must take a 240-hour inservice course after three years of teaching in order to be promoted to a higher salary scale. Secondary science teachers receive their training at national colleges of education from faculty in the chemistry, biology, physics, and earth science education department (UNESCO, 1985). Korea thereafter requires 60 hours of inservicing for science teachers every five years. This training is provided by city and provincial boards of education at regional science centers. Both programs are financed by the national government.

In the Philippines, science teachers can participate in a variety of workshops, seminars, and courses, designed to improve their science knowledge, their pedagogical skills, and their familiarity with new curricula and modern technology. These programs are provided by the Ministry of Education, Culture, and Sports; the Institute for Science and Mathematics Education Development; colleges and universities functioning as regional science teaching centers; and regional, divisional, and local science supervisors (UNESCO, 1985).

A number of countries have used the "cascade" model of science teacher training, that is they train "master" teachers to train other teachers. This may help solve the problem of spreading knowledge to more remote locations. The Regional Center for Science and Mathematics (RECSAM) in Malaysia has served as a training center for science teachers in Southeast Asia for many years. RECSAM courses may last up to 12 weeks; participants return to their own countries to provide inservice training to other teachers. One current program of interest at RECSAM is a pilot project called Thinking in Science and Mathematics (TISM), which is an inservice program for mathematics and science teachers at one school in Penang (SEAMO Quarterly, 1990). The project aims to improve teacher instruction and student learning through a constructivist approach to cognitive conflict.

The Indonesian teacher inservicing program described in detail below is an extremely well planned "cascade" model. This method of inservicing has been used in several countries including the United States, the United Kingdom, Malaysia, and Peru (Morris, 1990). ChemCom teacher training in the United States also employs the "cascade" model.

A number of science teachers' organizations are very active in providing teacher inservice programs. Both the Science Teachers' Association of Nigeria and the Ghana Association of Science Teachers provide workshops, seminars, and courses for science teachers in Nigeria and Ghana (Morris, 1990). The Hong Kong Association for Science and Mathematics Education has also run workshops and short courses, as has the science teachers' organization in the Philippines. Science teachers' organizations, as well as national scientific societies, have also conducted science teacher workshops, and seminars, and held teacher conferences in many Latin American, and Caribbean countries (Rodriguez, et al., 1989). Also, in addition to running workshops and courses, associations such as the Association of Physics Teachers in Argentina, and the Secretariat for Teaching Affairs of the Brazilian Society of Physics publish journals for their membership and other subscribers.
TABLE 3.7
Scope and Pattern of In-Service Teacher Education, India
(UNESCO, 1984)

<table>
<thead>
<tr>
<th>COURSE</th>
<th>DURATION</th>
<th>AGENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.Ed. correspondence</td>
<td>14 months correspondence + 4 months (2 summers) contact</td>
<td>Universities, regional colleges of education</td>
</tr>
<tr>
<td>M.Ed. correspondence</td>
<td>10 months correspondence + 1 month contact</td>
<td>Universities</td>
</tr>
<tr>
<td>Seminars &amp; symposia</td>
<td>1 week</td>
<td>NCERT, SCERT, SIE</td>
</tr>
<tr>
<td>Orientation</td>
<td>1-2 weeks</td>
<td>NCERT, RCEs, field offices, SCERT, SIE</td>
</tr>
<tr>
<td>Training</td>
<td>2-3 weeks</td>
<td>As orientation</td>
</tr>
<tr>
<td>Workshops</td>
<td>2-3 weeks</td>
<td>As orientation</td>
</tr>
<tr>
<td>Summer institutes</td>
<td>3-5 weeks</td>
<td>As orientation, KVS</td>
</tr>
<tr>
<td>Centers of continuing education</td>
<td>Weekends</td>
<td>NCERT, state education agencies</td>
</tr>
</tbody>
</table>

Key: NCERT - National Council of Educational Research and Training; SCERT - State Council of Educational Research and Training; SIE - State Institutes of Education; Regional Center of Continuing Education; KVS - Central Schools Organization

Another way to deliver science teacher education is through a distance learning program, usually developed by a university (see Table 3.8). This may involve a correspondence course, interactive radio learning, and TV, as well as a residential component. This mode of in-service education is found for science teachers in Columbia, Costa Rica, Equador, Guyana, and Jamaica. In Papua New Guinea, primary school teacher training in science is provided through interactive radio (Olsson, 1989). Distance learning is used especially to upgrade the content and pedagogical knowledge of teachers who are not fully certified. It is very important that if distance learning is being used to upgrade the knowledge of secondary science teachers that some component of the program brings participants together for at least several weeks. This is both to allow for laboratory-based instruction, and to permit teachers to interact and learn from each other in person.
TABLE 3.8

Distance Learning for Science Teachers, Some Examples

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>COURSE/(INSTITUTION)</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Namibia</td>
<td>Teaching methods/gen sci (The Academy)</td>
<td>1-year course, required for Higher Primary Ed. Cert., (HPEC)–correspond. course, tutor by mail/in-person</td>
</tr>
<tr>
<td></td>
<td>Subject didactics of elem. science</td>
<td>1-year course, Education Certificate Primary (ECP)</td>
</tr>
<tr>
<td>Nigeria</td>
<td>Integrated science (National Teaching Inst.)</td>
<td>Continuing ed., certificate–correspond., tutor in-person, weekend school, TV, radio, audiocassettes, vacation in-residence</td>
</tr>
<tr>
<td></td>
<td>BS honors (ed/biology)</td>
<td>Also prep. program for experienced teachers w/o science background–correspond., tutor in-person, radio, TV, cassettes, 1-week residential induction, 6-week residence in vacation, 7-10 year program</td>
</tr>
<tr>
<td></td>
<td>BS honors (ed/chemistry)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BS honors (ed/physics)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(University of Lagos)</td>
<td></td>
</tr>
<tr>
<td>Jamaica</td>
<td>Psychology, &amp; sociology of science teaching &amp; learning (UWI)</td>
<td>Certificate–teachers w. 10 yrs experience, 4 terms, correspond., interactive, w.practicum of 4-10 visits</td>
</tr>
<tr>
<td></td>
<td>Unifying concepts in science</td>
<td>As previous course</td>
</tr>
<tr>
<td></td>
<td>Nature of science/sci. enquiry</td>
<td>As previous course</td>
</tr>
<tr>
<td></td>
<td>Teaching methodologies in science</td>
<td>As previous course, all required cert. in integrated sci</td>
</tr>
<tr>
<td>Guyana</td>
<td>Emergency science program</td>
<td>Teacher training certificate program</td>
</tr>
</tbody>
</table>

It is beyond the scope of this limited study to survey the extent to which secondary science teachers are, in fact, receiving inservice education. However, a range of possibilities are suggested by Table 3.9; secondary science teachers in Thailand apparently receive more inservice education in one year, than Nigerian teachers receive in five years.
TABLE 3.9

Secondary Science Teacher Attendance at Inservice Courses
(Soydhurum, 1990a; Yoloe, 1989)

<table>
<thead>
<tr>
<th>COUNTRY/SUBJECT</th>
<th>NUMBER OF INSERVICE COURSES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
</tr>
<tr>
<td>Nigeria: Physics</td>
<td>60%</td>
</tr>
<tr>
<td>Chemistry</td>
<td>50%</td>
</tr>
<tr>
<td>Biology</td>
<td>49%</td>
</tr>
<tr>
<td>Math</td>
<td>55%</td>
</tr>
<tr>
<td>Ag. Sci.</td>
<td>57%</td>
</tr>
<tr>
<td>Health Sci.</td>
<td>60%</td>
</tr>
<tr>
<td>Average</td>
<td>55%</td>
</tr>
<tr>
<td>Thailand: Sec. Sci.(annual)</td>
<td>None</td>
</tr>
</tbody>
</table>

In the following section, two very different continuing education programs are described in some detail. Both are useful models for others to consider when planning inservice and onservice workshops for science teachers. A brief examination of these efforts makes clear that both projects have their priorities exactly right - i.e., they both demonstrate a seriousness of purpose related to teacher education. They make no attempt to "work around" the teacher, or to subvert the teacher’s classroom authority. They both recognize that there are no easy, or inexpensive, routes to teacher excellence. They both recognize that teacher continuing education is exactly that—a continuing process that should empower the teacher in the classroom, eventually leading to improved performance of the students.

(i) Indonesia

The Indonesian experience with the continuing education of secondary science teachers has developed considerably over the past 13 years. The current "cascade" (teachers training teachers) model of teacher continuing education evolved from a four-week series of regional workshops for secondary science teachers held between 1976-1978. The original model began with an orientation program for supervisors, head teachers, and other administrators in Jakarta. This was followed by a six-week training session for the instructors of the teachers, after which the actual teacher training workshops were implemented. Some 3300 secondary science teachers received training through this program. However, expected outcomes were not realized, so the program was redesigned (Somerset, 1988).

The newly designed inservice/onservice program, Pemantapan Kerja Guru (PKG—Strengthening the Work of the Teachers), began in late 1978 with the hiring of a full-time professional officer by the Ministry of Education and Culture. By the end of 1979, the first 12 teachers selected for training as PKG instructors were sent to the Regional Center for Science and Mathematics (RECSAM) in Malaysia for instructor training. The selection process included a battery of achievement and aptitude tests administered to teachers with at least five
years of teaching experience at an academic upper secondary school (Sekolah Menengah Atas – SMA), and a four-year undergraduate degree from either an institute of teacher education (IKIP) or a faculty of teacher education attached to a university (FKIP). The highest scoring teachers were interviewed and observed teaching in their own classrooms. Some 10-12% of the original applicants were selected for training as instructors.

The training process for these, and subsequent, instructors has included in-country English language training (10+ weeks); a three-month training session at RECSAM; travel study in Thailand and Australia; in-country preparation for the training sessions (4-6 weeks); and evaluation workshops at the end of each PKG training cycle. Selected teachers have received further specialist training including post-graduate studies overseas.

The initial PKG teacher training involved a cycle of two-weeks of inservice instruction at a regional or provincial center, six weeks of onservice instruction, two additional weeks of inservice training, followed by a final six weeks of onservice instruction. During the inservice component of the program teachers improved their content knowledge, explored various teaching strategies and means of assessment, practiced their laboratory skills, and took part in peer teaching exercises. Through 1988, teachers received an average of five visits from the PKG instructors during the on-service component of the program, obtaining feedback on their classroom performance and advice on how to improve classroom practice.

It was initially planned that all secondary science teachers in Indonesia would participate in two PKG cycles, covering the equivalent of two out of six semesters of the science curriculum. In practice, from 1979 until 1987, Somerset (1988) estimated that PKG coverage in science (there are parallel programs in mathematics and English) was about 0.4 cycles per teacher at the lower secondary level, and 0.8 cycles per teacher at the senior level.

As the PKG system developed, PKG teachers began to meet informally on Saturdays to cover areas of the curriculum not presented in their PKG cycle(s), and to share their knowledge with teachers who had not participated in PKG training. From this beginning in 1984, there developed a parallel teacher training system called the Sanggar PKG system, with financial support from a World Bank loan. The program offers one-week, non-residential training to large numbers of teachers, with the instruction provided by experienced PKG teachers (called guru inti, "key" teachers), identified as such by their instructors (see Figure 3.3). There is also a limited onservice component to the Sanggar PKG (SPKG) which, by 1988, had grown to 200 Sanggar teams (c.f., 26 PKG teams in 1988). The costs of one SPKG cycle are about one fifth of the PKG program; many more teachers have participated (by June 1987, almost 40,000 compared to just over 16,000 in the PKG program); but there has been a trade off in how much can be accomplished in a limited number of teacher contact hours (106 hours/SPKG cycle vs. 230 hours/PKG cycle).

There have been a number of problems with this dual system. All provinces have the same PKG training capacity, but very different numbers of teachers. The SPKG program has attempted to accomplish two very different tasks within the same program: reach unqualified teachers who have not attended the regular PKG program, and continue the training of the PKG teachers. In reality, the former group require longer courses; the latter do not need the onservice component. The guru inti have received no special training and may have less formal education than some of the SPKG participants. Also, there is a need for more trained PKG instructors and for additional training for program administrators (World Bank, 1989).
Figure 3.3  The Initial PKG and Sanggar PKG Systems
(Somerset, 1988)

PKG System

National Team
- PKG Officers, National & International Consultants

Provincial Teams
- PKG Instructors

Classroom Teachers

Sanggar PKG System

Selected Classroom Teachers–Guru Intl

Other Class Teachers
The Modified Sanggar-based PKG System

A. National Team receives inservice internationally
B. Instructors receive inservice from National Team
C. Instructors monitored onservice by National Team
   Guru Intl receive inservice from Instructors
D. Guru Intl monitored onservice by Instructors
   Teachers receive inservice from Guru Intl
E. Teachers monitored onservice by Guru Intl
   Teachers deliver instruction to students

Source: World Bank, 1989
Most importantly, the program has not established any formal linkages with the preservice teacher training institutes, nor with the subject matter teacher organizations. The recently initiated Bank-funded modified PKG/SPKG program (see Figure 3.4) attempts to address the above concerns through reforms in three areas: the program, related materials production, and organization structure and management. The existing PKG program will be decentralized by shifting its focus from the provincial to the district level, and transferring responsibilities from the PKG instructors to the guru intls. The number of training teams in a province will depend on the teacher population in that province. Instruction at the district and school levels will become integrated with programs of the teacher associations.

Subject matter consultant boards will be formed consisting of teams of national and international consultants to provide oversight and evaluation of the new program as it develops. Formal contracts with overseas universities will provide consultants and training. Faculty from local teacher training institutions will be used as provincial consultants on a regular basis to bridge the gap between the preservice programs and the PKG program. Also, a few PKG instructors will join the faculty of these institutions.

More PKG instructors will be trained through national and international programs. Over a five-year period there will be some 60 master's degree-level instructors produced from a cadre of about 72 teachers. The guru intls will receive inservice and onservice training (two sessions each of one-year in length). Some 5,760 guru intls will be trained. Several will qualify as full PKG instructors after additional training. Assistant guru intls will then be promoted to fill the vacancies. Career ladders will be defined for teachers and administrators within both the PKG and school systems.

The new program will provide pedagogical and managerial training to all secondary school principals, made possible by recruiting more trainers of principals. Selected principals will receive training overseas. Supervisors and provincial heads of secondary general education will also receive in-country and international training.

PKG instructional materials, including teacher notes, worksheets, tests, and ancillary teaching materials will be prepared for publication. They will then be distributed to all schools, together with national 1984 curriculum guidelines.

The management structure of the program will be clearly redefined to include specific job descriptions, and will be contained within a separate organizational unit of the Directorate of General Secondary Education, Ministry of Education and Culture. A computerized national data base will be established to provide accurate information on the extent of program implementation, and to provide the data necessary for a valid evaluation of its effectiveness.

Upgrading teacher training through strengthening the PKG/SPKG program accounts for some $82.5 million of a $223 million project. Support of educational management accounts for an additional $19.8 million. This is clearly an extremely ambitious project. Its designers have realized that teacher education is a continual need and that, for teacher quality to be maintained, this program must be sustainable. They are also working on establishing those organizational structures necessary for institutional reform.

(ii) Venezuela

The Venezuelan Centro Nacional para el Mejoramiento de la Ensenanza de la Ciencia (CENAMEC) was established by presidential decree in 1973. The Center was "created with the objectives of providing continuous and systematic attention in an organic fashion to the improvement and updating of the teaching-learning process in science" (Rada, 1986). Its mission statement continues "The Center will operate and conduct
activities at all educational levels with the objective of attaining the improvement of teaching methods and media, and the training and improvement of teachers, to stimulate teachers and students alike to develop creative, inquiring and active minds.

The Center originated as a cooperative effort between the National Council for Scientific and Technological Research (whose mission is to promote inter-institutional cooperation related to research), and the Ministry of Education. From its inception the Center has been concerned with bringing scientists from both academe and industry together with educators to conduct educational research, and design and test programs to improve the quality of science instruction in Venezuela. The Center's programs are innovative and experimental; they are models for others to copy. They involve partnerships with universities and pedagogical institutes, both public and private, and with large industrial corporations (CENAMEC, 1991a). Center activities are used to support the formulation of national policies related to science and mathematics education (Rada, 1986).

The Center operates in five basic areas: curriculum development in science and mathematics at the basic and diversified levels; production of low-cost equipment using locally available materials; collection of educational statistics to determine the effectiveness of programs; support of out-of-school science activities, both to encourage student interest in careers in science and to promote science to the general public; and, design and implementation of teacher training workshops (CENAMEC, 1991b).

The teacher training workshops, of varying length and cost, are developed through an experimental model, which is based on past national and international experiences and research. When teachers are expected to introduce new instructional materials into the classroom, their own knowledge and attitudes in the area are incorporated into the workshops' content and strategies (see Figure 3.5). It is assumed that teachers have the same misconceptions as their students. This is a constructivist model of workshop design. The experimental workshops are piloted, and then both the program and the instructional materials are modified based on experience. The redesigned workshops are then held and evaluated by the teachers. The instructional materials are assessed in the classroom in terms of the students' gains in achievement. Both components of this evaluation are fed back into the system, to refine the design and content of subsequent workshops (de Bascones, 1988).

Since its beginning, CENAMEC has provided workshop training to many thousands of science and mathematics teachers at both the basic and diversified levels of education (Rada, 1986). The Center has also conducted seminars for national and international science educators at the tertiary level. As one example of its workshop efforts, from 1976 to 1984, CENAMEC ran 27 workshops for 685 secondary chemistry teachers to introduce them to the project "The Environment: a Resource for Chemistry Learning" (Pujol, 1990). The teachers had an opportunity to design instructional units that integrated environmental issues with chemical principles. Many of these same units are being incorporated into the new chemistry course developed by the Center. The provision of a well-designed teacher continuing education program is considered essential to the successful implementation of the new course.

The Status of the Science Teacher

Whether or not an able student decides to become a teacher, or a qualified teacher chooses to stay in the teaching profession, depends on two factors: the actual and perceived rewards of teaching, and opportunities for employment in other professions. For students who are scientifically gifted the main consideration is usually the second factor. For science students, the choice of teaching is most frequently the fall-back position, since, throughout the world, science research has a much higher status than secondary science.
Figure 3.5
Structure of In-service Teacher Training Workshops
(de Bascones, 1988)
teaching. Those students with both the talent, and the opportunity, tend to go on to earn a science doctorate; they rarely become secondary school teachers.

The bright, but not necessarily gifted, graduates with an undergraduate science degree may choose between employment in business and industry and a career in teaching. Since employment in industry is likely to pay more than teaching, once again teaching may be the default selection. It could be argued that the availability of jobs in industry for BS graduates is a positive indicator of economic growth. However, if talented science students do not enter teaching, who will teach the next generation of scientists? Who will have the intellectual background to make science comprehensible, and useful, to future citizens? The students who are currently entering teacher education programs tend to be the lower achieving of the college-bound. This is true for countries as disparate as the United States, Indonesia, Nigeria, and Brazil.

What incentives are there to attract the better students to science teaching? In developing countries, teacher pay tends to be low compared to other professions requiring similar academic qualifications. Textbooks and other support materials are often in short supply; also, other working conditions especially in the rural areas may be inadequate; continuing education opportunities may be rare; and career ladders may be nonexistent.

Paradoxically, efforts to enhance the preservice education of future teachers may make them more employable in other professions. This happened to a highly trained group of science and mathematics teachers in Guatemala in the 1970s, most of whom left their model preservice education program to become electrical engineers, biochemists, pharmacists, and technical professionals in other fields (Rodriguez, et al., 1989). These were the teachers needed to nurture the next generation of scientists and engineers.

Shortages of qualified science teachers are widely reported in Africa. In Nigeria, for example, there is a dangerous shortage of qualified chemistry and physics teachers, with the latter reported in especially short supply (Yoloye, 1989). One indication of such a shortage is the number of expatriate teachers employed as secondary science teachers. In Senegal, 17% of science teachers are expatriates, in Burkina Faso 7%, and in Papua New Guinea 16% (Caillods and Gottelmann-Duret, 1991). A shortage of qualified physics teachers is a problem throughout Latin America and the Caribbean being, apparently, especially acute in Jamaica (Rodriguez, et al., 1989). In Pakistan in 1985, there was a 24% vacancy rate for science teachers at the middle and secondary schools levels (Asian Development Bank, 1985). Of those who were employed, more than 50% were either untrained or underqualified.

Lockheed and Verspoor (1990) have described the widespread need for primary teachers to work at several jobs to earn a living wage. This is also a problem at the secondary school level. Where teachers' salaries are so low that secondary science teachers must work at more than one job to survive, it is impossible for them to upgrade their own educational backgrounds. Teaching quality suffers, homework is never marked, teachers barely know their students, and absenteeism rises to crisis levels. In many Latin American countries (e.g., Argentina, Brazil, Chile, Columbia, Ecuador, Guatemala, and Mexico), teachers may work part-time at two or three different schools to earn a living wage. Here, secondary teacher salaries are very low compared to other professionals with equivalent qualifications (Rodriguez, et al., 1989). However, despite the poor pay, there is still intense competition to enter the teaching profession in some Latin American countries. This may be because of a lack of other employment opportunities, the stability of teaching as a profession, and the availability of part-time teaching jobs to supplement income.

Secondary school teacher salaries are also low in many African countries, although usually much higher than the salaries of primary teachers (Kelly, 1991). The expansion of the secondary teaching force over the past 15 or so years has contributed to this problem. Inflationary forces have also exacerbated the situation. In Zambia, from 1975 to 1985, apparent gains in teachers' salaries were completely eliminated by inflation. A teacher's 1985 salary was worth about 60% of its 1975 value. When special teaching allowances were considered together with base pay, although the total earnings of secondary school teachers in Zambia rose by 52% over
the 10-year period, in constant prices they actually fell by 32%. In Zambia, as in other African nations, secondary school teachers are working at more than one job in order to survive.

(Surprisingly, Kelly has reported that in spite of adverse conditions, the Zambian teaching profession is becoming "more professional, more highly motivated, and more confident of its ability to master the adverse circumstances that have beset it." He credits the Zambian teachers' Self-help Action Plan for Education, the SHAPE movement, a program "of the teachers for the teachers by the teachers," as instrumental in raising the morale and professional awareness of teachers.)

In Nigeria, the low salaries of secondary school teachers are considered a very serious problem by 30% of science teachers, and a serious problem by 33% (Yoloye, 1989). Nigerian science teachers are also dissatisfied with their conditions of service; in this same survey 66% considered these conditions to present a serious, or very serious, constraint to teaching secondary school science in Nigeria. According to Collison (1984), the low salaries of secondary teachers in Ghana have contributed to that country's shortage of physics teachers (see Table 3.10).

Secondary school teachers in Sri Lanka were once relatively well paid and had high status in the community. With the rapid expansion of secondary education in Sri Lanka, and the consequent employment of many more often marginally qualified teachers, there has been an erosion in both the status and pay of secondary school teachers (World Bank documents).

In an effort to attract more students to teaching careers, in the late 1980s the Pakistani government introduced advanced teaching contracts supported with stipends, to science graduates willing to enter secondary school teaching. A special supplemental monthly allowance has also been provided to secondary science teachers with both subject matter and pedagogical qualifications. An increased availability of continuing education opportunities for secondary science teachers, also makes the job more appealing.

Teaching in Japan, where there is no shortage of secondary school teachers, is a socially respected, and relatively well paid occupation. The high pay of Japanese teachers is a recent phenomenon, occurring within the past 30 years. In 1984, the beginning salary of a Japanese secondary school teacher with an undergraduate degree was 12% higher than a beginning engineer with a BS degree, and 15% higher than the starting pay of a white-collar worker with equivalent qualifications. By mid-career, the salaries are about the same. However, after 30 years of service the teacher again earns a comparatively higher salary (U.S. Department of Education, 1987). After 37 years of service, the Japanese secondary school teacher with a bachelor's degree earns 2.98 times her entry salary (Barro and Suter, 1988).

Figure 3.6 shows the ratio between the entry-level and top-of-the-scale salaries of secondary school teachers with a bachelor's degree in selected countries. The graph can lead to wrong conclusions, because it does not compensate for the fact that teachers in different countries receive very different compensation packages in addition to salary. Nor does it take into account variations in service from country-to-country, such as instructional hours, pupil load, non-teaching responsibilities, etc. What it does do is show the value placed on seniority in both Japanese and Korean schools.

Certainly a low salary is not the sole determinant of teacher status and morale, nor is it the factor which can be most easily dealt with. As mentioned previously, the availability of continuing education opportunities is also perceived as valuable by the teacher. Other possible ways to enhance the status of secondary science teachers are given in Chapter 6 (q.v.).
<table>
<thead>
<tr>
<th>Country</th>
<th>Status</th>
<th>Indicators of Status</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>High</td>
<td>(i) Av. salary higher than other public employees, compares well with profs. in private sector. Salary increases made in 1974 to attract better qualified to teaching. (ii) Competition pressure to enter teaching high. (iii) Teachers given authority as well as responsibility</td>
<td>US Dept. of Ed., 1987</td>
</tr>
<tr>
<td>Korea</td>
<td>High</td>
<td>(i) 1983 elementary teachers pay equal to captain in army. (ii) 1984 average teacher salary more than average for all professionals but less than all managers (1.2 : 1 : 1.5)</td>
<td>Amsden, 1989</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>In decline</td>
<td>(i) Once well-paid, high status—salary loss to inflation, expansion of secondary system (ii) Poorly trained teachers in school, morale low.</td>
<td>World Bank, 1989</td>
</tr>
<tr>
<td>Ghana</td>
<td>Low</td>
<td>(i) Science teachers salaries low compared to higher status jobs in Industry &amp; Civil Service. (ii) Shortage of physics teachers.</td>
<td>Collison, 1984</td>
</tr>
<tr>
<td>Nigeria</td>
<td>Low</td>
<td>(i) 63% science teachers dissatisfied with salaries; 66% dissatisfied with conditions of service. (ii) lack of qualified teachers (especially chemistry and physics considered serious or very serious.</td>
<td>Yoloye, 1990; Ivowi, 1991</td>
</tr>
<tr>
<td>Brazil</td>
<td>Low</td>
<td>(i) Salaries so low teachers need more than one job to survive. (ii) (ii) Male secondary teachers salaries comparable to male clerks. (iii) Job compet. high but probably for job security and part-time jobs.</td>
<td>Rodriguez, et al 1989; Psacharapoulos, 1987</td>
</tr>
<tr>
<td>Equador</td>
<td>Low</td>
<td>(i) Salaries v. low compared to other professionals. (ii) Teachers work several jobs</td>
<td>Rodriguez, et al 1989</td>
</tr>
</tbody>
</table>
The Changing Role of the Teacher

The trend toward "science for all" has, as indicated in Chapter 1, placed the science teacher in a challenging new position. Not only is the teacher being asked to become familiar with the content of what are, most likely, unfamiliar disciplines, but the role of the teacher in the classroom is expected to change from that of "conveyor" of knowledge to that of "manager" of the learning process.

The inadequate science background of science teachers in many countries has already been discussed. Even teachers who were initially well-prepared in science content when entering the teaching profession may have little understanding of the practice and direction of modern science. The need for ongoing teacher continuing education exists, whether or not curriculum change is planned.

Figure 3.6
Salary Relative to Seniority, Secondary School Teachers

If curriculum reform is planned, however radical or otherwise that reform, both the subject-matter competence of secondary science teachers and their understanding of modern teaching practices, becomes a limiting determinant of the success of the effort. Given the trend to cross- or inter-disciplinary science courses, the danger is in moving from a situation where one science is poorly understood to one in which several sciences, and the relationships between them, are completely misunderstood.
The role of the teacher in the classroom is being redefined. The "chalk and talk" delivery of science facts and concepts, so prevalent in classrooms around the world, becomes completely obsolete, not to mention counterproductive, when the teacher is being asked to:

- teach science as a "way of knowing";
- shape student attitudes and values toward science, technology, and the environment;
- alter student behaviours related to their use of science knowledge outside the classroom; and,
- develop the students' decision-making skills related to science and society issues.

The many competencies required in order to function as a "science teacher for all" were discussed in some detail at the Regional Training Workshop for Science Curriculum Developers and Teacher Educators, organized by the UNESCO Regional Office for Education in Asia and the Pacific in Islamabad, Pakistan, in October 1985. Conference participants from 15 countries defined a number of basic roles for the science teacher (UNESCO, 1989). These roles can be simplified as follows:

- **Community Development Worker**— The teacher acts as an "agent of social change," assisting the community in undertaking sustainable development projects that address national goals, and in understanding the consequences of action, or inaction.

- **Investigator/Learner**— The teacher is an information locator and disseminator to both students and the community, thus contributing to both the students' knowledge and the communal decision-making process. The teacher is also a life-long learner.

- **Motivator**— The teacher's traditional role of motivating the student in the classroom is also extended to out-of-classroom activities.

- **Curriculum Developer**— The teacher becomes an active participant in the shaping, evaluation, and classroom modification of curricular materials.

- **Evaluator**— The teacher assesses student performance and devises ways to enhance that performance.

- **Interpreter of Technology**— The teacher serves as an interface between technology and the community, and as a liaison to the scientifically and technologically rich sectors of the economy.

Clearly the knowledge, skills, and attitudes required of such a teacher are well beyond the norm for any country. Assigning the role of change agent to a teacher is not a new idea, but the expectation that overworked, underpaid, and underappreciated science teachers will take on this role is unrealistic.
Overcoming Teacher Resistance to Change

The inservice education of science teachers must be carefully planned. The difficulty of getting teachers to accept innovation in the classroom should never be underestimated. As mentioned previously, teachers will teach the way they are taught. Hence, a lecture-based exhortation to improve practice is rarely effective. Both Sparks (1983) and Wade (1984/85) in separate meta-analyses of teacher development programs identified the following components as essential to an effective program: (i) a diagnostic/prescriptive phase to heighten teacher awareness of the need for change; (ii) the presentation to teachers of what they are to learn, and how this will be of use to them; (iii) a modeling of the desired teaching behaviours by the course presenters; and, (iv) practice teaching by course participants, including peer feedback, videotape analysis of performance, etc.

Work conducted at the University of Texas at Austin in the early 1970s identified a developmental progression of teacher concerns related to their eventual adoption (or rejection) of innovation in their own classrooms (Hord et al., 1987; Hall et al., 1979; Hall, 1978). Teachers progress along this chain, from an initial awareness of the need for change, through concerns based first on self-adequacy, and subject matter and teaching skills competence (can I do this?); to concerns related to the logistics of implementing reform (how do I do this?); to concerns related to the impact on the student (what will be the result if I do this?).

The developers of this Concerns-Based Adoption Model (CBAM) for teacher acceptance of change emphasize that change cannot be imposed on teachers by administrative fiat, but that it is a slow process requiring the careful nurturing of individual teachers, as they move through the identifiable stages and levels of concern. The change process is too delicate to rush; the change facilitator must begin by carefully establishing an awareness in each teacher of the need for change, timing and adapting program strategies to match the concerns of the teacher.

In their analysis of the Science Education Project (SEP) in South Africa and Namibia, Macdonald and Rogan (1990) examined the effect of context on implementing classroom change. The project began in the late 1970s as an effort to bring more "hands-on science instruction into rural, black schools in the Ciskei. By 1987, the project had expanded to include teachers from some 2,000 rural and urban schools, serviced by program "implementers" located in 12 regional centers. The implementers work with teachers to upgrade their subject matter competency, and knowledge of innovative teaching techniques.

The teachers (and their students) have been particularly uncomfortable with highly interactive styles of science teaching, a reaction also reported by Buseri (1987) and Ogunsiji (1983) for Nigerian classrooms; Kay (1985) for Kenyan classrooms; and Hacker (1984) for Australian classrooms. These reports also confirm that science teachers who are insecure in their subject matter knowledge tend to resort to "chalk and talk" teaching.

Macdonald and Rogan (1990) have hypothesized that there are a number of other factors involved in this discomfort apart from teacher insecurity: (i) culturally determined expectations of teacher/student behaviors in the classroom (reinforced within the school by the reliance of non-science teachers on the lecture-method); and, (ii) a culturally distinct view of the nature of science knowledge. They have noted that teachers who have worked with SEP have moved toward a more interactive style of teaching, but that this shift has taken time. To bring about this shift, the project is structured to take teachers gradually from an understanding of subject matter and use of equipment (content phase), to establishing a familiarity with new teaching methods (methods phase), to redefining personal teaching objectives (aims phase).
Macdonald and Rogan have concluded:

"Not only is it possible that too little account of contextual factors is taken in planning educational innovations, but our experience has shown that despite the best intentions, unanticipated contextual factors emerge even as apparently successful implementation proceeds."

If science teachers in developing countries are to become "change agents," as has been suggested, then a sustained program of teacher continuing education must be developed with very careful planning, and a real appreciation of the complexity of successfully implementing educational reform.

Discussion

In his report for the World Bank on improving teaching, Verspoor (1986) clearly recognized the pivotal role of the teacher in implementing successful educational reform. His recommendations related to all teachers; they are very applicable to science teachers. They were: provide locally available and permanent inservice education; create systems to supervise and support teachers; design workshops based on teachers' needs and knowledge; and, find ways to motivate teachers.

While there is a need to reform preservice science teacher training, given the large number of unprepared teachers now in the profession (most of whom are still young, with years of teaching ahead), the first priority must be to make appropriate continuing education available to all science teachers. If a new textbook is introduced, teachers need workshops to introduce them to material presented in a different context — this is necessary even if the material is itself familiar. If new ancilliary workbooks are provided, teachers need to know how to use them. There is NO "teacher-proof" curriculum — no matter how well-designed.

If laboratories receive new equipment, whether it be high-tech or low-cost, locally built, the teachers need instruction on the use, and maintenance, of that equipment. If special science kits are introduced into the classroom, whether or not they are designed to work with, or around, the teacher, teachers need workshops on how to use them. As indicated previously, pre-designed and pre-assembled kits may be useful in the short-term. In the long-term they avoid the real issue — the ability of the teacher to teach science effectively to both future scientist and future citizen.

No effort to improve secondary science education will succeed if the teachers are either ignored, excluded from the decision-making process, or are considered more of a problem than the eventual solution to the problem. Sustainable reform of science education in any country ultimately depends not on a carefully thought out decision on what science to teach (although this decision must be made) but on: attracting the brightest and the best into science teaching; preparing them to teach effectively; providing continuing opportunities for them to upgrade their knowledge and skills; and retaining them in the profession.

Power (1986) summarized the educational needs of science teachers as follows:

"Continuous development implies an orderly progression to increasingly higher levels of expertise as a teacher and as a member of a professional community as a result of the enrichment, refinement and integration of knowledge and abilities which constitute domains of professional competence. These domains include curriculum planning, development and implementation; communication and interpersonal relations; teaching strategies for new programmes and difficult topics; individualising instruction; diagnosing and helping students with special needs; assessment; sensitivity to the socio-cultural-employment context; study of, and critical reflection on, one's teaching in the light of developments within education, research and theory in science/technology/mathematics."
The Purposes of Assessment

Assessment is an integral component of teaching with many possible purposes. The recording and reporting of student achievement serves both formative and summative purposes for individual students, and groups of students (see Figure 4.1). Assessment is used to monitor a student's progress; motivate the student toward higher achievement; diagnose the learning difficulties of the individual student; and offer remediation (formative/individual quadrant). Student final grades on examinations or class work are used as a means of selecting those few who will be given the opportunity to continue with their education (e.g., from secondary to tertiary levels); to certify a particular level of educational attainment; and to predict future educational achievement (summative/individual quadrant).

Figure 4.1

**Assessment Functions**  
(Pennycuick, 1990)

<table>
<thead>
<tr>
<th>FORMATIVE</th>
<th>SUMMATIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INDIVIDUAL</strong></td>
<td><strong>GROUP</strong></td>
</tr>
<tr>
<td>Student motivation</td>
<td>Teacher motivation</td>
</tr>
<tr>
<td>Monitoring, feedback guidance</td>
<td>Feedback on teaching</td>
</tr>
<tr>
<td>Diagnosis &amp; Remediation</td>
<td>Curriculum evaluation</td>
</tr>
<tr>
<td>Recording &amp; reporting of attainment</td>
<td></td>
</tr>
</tbody>
</table>
Assessment is also used to motivate teachers; to provide teachers with feedback on the effectiveness of their teaching; and to permit an evaluation of the curriculum, including the extent to which it is delivered by teachers and perceived by students as intended by curriculum developers (formative/group quadrant). Finally, assessment is used as a device to improve the curriculum, perhaps by redefinition of curriculum content; as an accountability measure for the entire system; and to set national standards defining acceptable quality in all facets of teaching and learning, including the conditions under which they should take place (summative/group quadrant).

There are many issues to be resolved regarding the reliability and validity of assessment systems and instruments used for varying purposes around the world. It is beyond the scope of this particular study to provide an in-depth analysis of these issues. Instead, after a brief, non-technical overview of assessment, this chapter will focus on some of the concerns related to assessment that are especially relevant to science education reform. They are: (i) the relationship between assessment and reform; and, (ii) the value of international assessments in science as a means of promoting reform.

Assessment Systems Around the World

While the regular assessment of student performance for formative purposes is a feature of instruction in all classrooms, the summative assessment process can be the responsibility of the school (internal assessment), or some outside authority (external assessment). The external authority may be an examining board/service connected to a university system, a regional or state government department, or even a private organization.

There are also educational systems which combine both external and internal assessment (see Table 4.1 for European examples). Countries which have internal assessment systems at the lower secondary level, may move to a more externally-based process at the upper secondary level, where these examinations are used for university entrance (Kreeft, 1991). At the upper secondary level, although Spain, Portugal, and Greece use internal assessment for school leaving certification, university entrance in these countries is based on external examinations.

External assessment of student performance depends on the validity and reliability of standardized tests which are designed to evaluate either the achievement or the aptitude of a student in a subject or range of subjects. In practice, the separation between achievement and aptitude is often imprecise, with so-called aptitude tests containing achievement components. The advantages and disadvantages of these two kinds of tests are summarized in Table 4.2.

Standardized tests may consist of multiple-choice or essay questions; they may include an oral or a practical component (see Table 4.3). Individual test scores may be norm-referenced (i.e., compare an individual student's score with those of other students) or criterion-referenced (i.e., compare an individual student's score with some predetermined standard).

Continuous, school-based assessment has been a feature of the standardized examination systems of a number of developing countries for some time. For example, since 1982 the grades 10 and 12 leaving examinations in Papua New Guinea have comprised 50% school-based continuous assessment, and 50% a standardized external examination (Lewin, 1991; Pennycook, 1990). The school-based component of the examinations as defined by the PNG Department of Education may include:

- Classroom tests set by the teacher to cover both fact and concept knowledge and thinking skills (70%-80%);
- 87 -

- written assignments from both class and homework activity (<10%);
- project work (<10%); and,
- practical tests of experimental design and manipulative skills proficiency (<10%).

**TABLE 4.1 Characterization of Examinations**
(Kreeft, 1991)

a) Lower Secondary School

<table>
<thead>
<tr>
<th>External Assessment</th>
<th>Mixed Systems</th>
<th>Internal Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>75% / 25%</td>
<td>50% / 55%</td>
</tr>
<tr>
<td></td>
<td>25% / 75%</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Irland</th>
<th>Netherlands</th>
<th>FRG</th>
<th>FRG</th>
<th>Belgium</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Denmark</td>
<td>south</td>
<td>north</td>
<td>Luxembourg</td>
</tr>
<tr>
<td></td>
<td>France</td>
<td></td>
<td></td>
<td>Italy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Spain</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td>Portugal</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Greece</td>
</tr>
</tbody>
</table>

b) Upper Secondary School

<table>
<thead>
<tr>
<th>External Assessment</th>
<th>Mixed Systems</th>
<th>Internal Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>75% / 25%</td>
<td>50% / 50%</td>
</tr>
<tr>
<td></td>
<td>25% / 75%</td>
<td>100%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>France</th>
<th>Netherlands</th>
<th>FRG</th>
<th>Belgium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ireland</td>
<td>Denmark</td>
<td>south</td>
<td>Spain</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>Italy</td>
<td>north</td>
<td>Portugal</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Greece</td>
</tr>
</tbody>
</table>
TABLE 4.2
A Comparison between Aptitude and Achievement Tests
(After Heyneman, 1988)

<table>
<thead>
<tr>
<th></th>
<th>Aptitude</th>
<th>Achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantage</strong></td>
<td><strong>Disadvantage</strong></td>
<td><strong>Advantage</strong></td>
</tr>
<tr>
<td>Not dependent on common</td>
<td>Does not reinforce content</td>
<td>Encourages learning of specific knowledge</td>
</tr>
<tr>
<td>curricula, thus broadly</td>
<td>learning</td>
<td></td>
</tr>
<tr>
<td>applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less dependent on</td>
<td>Still considered culturally</td>
<td>Exam feedback permits</td>
</tr>
<tr>
<td>cultural factors thus</td>
<td>biased</td>
<td>identification of problem</td>
</tr>
<tr>
<td>more equitable</td>
<td></td>
<td>areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not as subject to</td>
<td>Not as subject to</td>
<td>Can be coached</td>
</tr>
<tr>
<td>coaching as</td>
<td>coaching as</td>
<td></td>
</tr>
<tr>
<td>achievement tests</td>
<td>achievement tests</td>
<td></td>
</tr>
</tbody>
</table>

Since 1976, continuous assessment has also been a feature of the standardized examination system in Tanzania (Pennycuick, 1990). Here the concern has been to give students a greater opportunity to succeed than might be possible in a system where one examination decides all.

Sri Lanka is currently introducing the continuous assessment of school assignments and projects as a component of its O-level certification process for years 9-11. This move is to permit the evaluation of a broader set of objectives than the written examination, and to use assessment as a means of remediation for poor student performance (Pennycuick, 1990). The informed involvement of principals and teachers in the assessment process is considered essential to its success. In Sri Lanka, some 30,000 teachers will need in-service training in continuous assessment techniques to prepare them for the full implementation of this system.

Assessment and Reform

In developing countries, assessment tends to be viewed from its summative/individual aspects, rather than as an opportunity to improve and redefine the entire system—from teacher classroom behaviors to curriculum content. Of even greater concern is the extent to which the standardized examination system actually impedes reform, rather than promoting it.

For example, the Malaysian Integrated Science Curriculum introduced in the early 1970s was a discovery and process-oriented course, designed to introduce experiential science to students. The accompanying standardized examination included no practical testing, emphasized recall questions, and contained no questions related to attitudes, and few questions on applications (Lewin, 1984). As another example, in francophone Africa where school leavers take the Baccalaureate examination, science courses tend to be traditionally academic, with science and society content kept to a minimum.
### TABLE 4.3 Internal/External Assessment

<table>
<thead>
<tr>
<th>Country</th>
<th>School Assessment</th>
<th>External Assessment</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>y/n</td>
<td>y/n</td>
<td>Apt</td>
</tr>
<tr>
<td></td>
<td>Comments</td>
<td>ob/ es</td>
<td>ob/ es</td>
</tr>
<tr>
<td>Australia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-67</td>
<td>y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/8-10</td>
<td>y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11/12</td>
<td>y Some states</td>
<td>y</td>
<td>*</td>
</tr>
<tr>
<td>Canada</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-12/13</td>
<td>y</td>
<td></td>
<td></td>
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<tr>
<td>France</td>
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<tr>
<td>9</td>
<td>y</td>
<td>y</td>
<td>*</td>
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<td>12</td>
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<td></td>
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<tr>
<td>Germany</td>
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<tr>
<td>9</td>
<td>y</td>
<td>y</td>
<td>*</td>
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<tr>
<td>10</td>
<td>y</td>
<td>y</td>
<td></td>
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<tr>
<td>13</td>
<td>Not Bavaria, Baden. Some states</td>
<td>y</td>
<td></td>
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<tr>
<td>Hong Kong</td>
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<tr>
<td>11</td>
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<td>*</td>
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<td>13</td>
<td>y</td>
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<td>India</td>
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<td>Italy</td>
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<td>8</td>
<td>y Part Ext. committee</td>
<td>y</td>
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<td>13</td>
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<tr>
<td>Malawi</td>
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<td>12</td>
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<td>Malaysia</td>
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<td>3 &amp; 5</td>
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<tr>
<td>12</td>
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</tr>
</tbody>
</table>

**Key:** Apt - Aptitude test; Ach - Achievement test; ob - objective test; es - essay  
**Source:** Kreeft, 1990.
<table>
<thead>
<tr>
<th>Country</th>
<th>School Assessment</th>
<th>External Assessment</th>
</tr>
</thead>
<tbody>
<tr>
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<td>y/n Comments</td>
<td>y/n Apt</td>
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<tr>
<td></td>
<td></td>
<td>ob</td>
</tr>
<tr>
<td>Nigeria</td>
<td>y y y y</td>
<td>y</td>
</tr>
<tr>
<td>6</td>
<td>Primary leaving</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Sec. entrance exam. School</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Certificate Higher school cert.</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Netherlands</td>
<td>y LBO-lower voc ed</td>
<td>y</td>
</tr>
<tr>
<td>12</td>
<td>LBO-lower voc ed</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>MAVO-lower gen</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>MAVO-lower gen</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>MAVO-lower gen</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>HAVO-higher gen sec</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>HAVO-higher gen sec</td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>y y y y</td>
<td>y</td>
</tr>
<tr>
<td>9</td>
<td></td>
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<td>10/11</td>
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<tr>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uganda</td>
<td>y y y y</td>
<td>y</td>
</tr>
<tr>
<td>7</td>
<td>Primary leaving</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Cert. of ed</td>
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</tr>
<tr>
<td>13</td>
<td>Advance cert</td>
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</tr>
<tr>
<td>UK</td>
<td>y y y y</td>
<td>y</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USA</td>
<td>y y HS diploma</td>
<td>y</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>y y Eval &amp; cert</td>
<td>y</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11/12</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key: Apt - Aptitude test; Ach - Achievement test; ob - objective test; es - essay
Source: Kreeft, 1990.
All teachers are judged by their students' performance on standardized tests. Science teachers, faced with an overcrowded curriculum, are very much under pressure to cover all the topics that may appear on the standardized examinations. A primacy is placed on teaching techniques which permit the teacher to cram as much knowledge as possible into students for a long enough period of time to be recalled for the examination (i.e., "chalk and talk"). Whether or not students really understand the concepts or not is barely the issue. The introduction of material into the lesson which is not included on the final test may be actively resisted by the students.

A number of developing countries have been exploring ways to use standardized examinations to change science curriculum content. The section that follows discusses: (i) the apparent dissonance between the objectives of the new O-level science curricula in Nigeria compared to questions found in the examinations; (ii) a new school-leaving examination in China; (iii) the use of standardized examinations to facilitate the introduction of environmental topics into science courses in the Caribbean; and, (iv) the use of feedback from the old Certificate of Primary Education Examination in Kenya to improve instruction in science.

(i) Examination and Curriculum Reform in Nigeria

Adamu (1991) analyzed questions from the newly introduced Nigerian O-level Senior School Certificate Examinations (SSCE) in biology, chemistry, and physics in terms of the performance objectives they were apparently assessing. These objectives were compared with the distribution of performance objectives in the curriculum guidelines issued by the Nigerian government. As shown in Table 4A, these two sets of objectives do not match well. For example, while 35% of the objectives of the new science curricula could be categorized as "knowledge recall" objectives, 47% of the questions on the examinations assessed knowledge recall. Some 32% of the curricular objectives involved comprehension of knowledge, but only 24% of the examination questions addressed comprehension. While 11% of the curricular objectives were classified as psychomotor, there was no testing of psychomotor skills in the examinations.

Classroom observations to determine the extent to which teachers implemented the intended curriculum showed that the teachers continued to teach toward the examination, in a lecture mode, emphasizing the importance of knowledge recall to their students. Adamu concluded that:

"...it is not enough to merely improve the curriculum by changing its objectives and introducing words with social and developmental dimensions. A whole range of integrated science curriculum development strategies has to be developed for Nigeria [or for any country]. This should see science education not merely as a list of impressive and politically significant objectives which policy makers and curriculum developers hope will be attained by students, but as a dynamic classroom process which reflects itself both in its statements of intent and in the examination system."
TABLE 4.4

Performance Objectives In Curriculum vs. Questions in Examination
(Adamu, 1991)

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>BIOLOGY 1=348</th>
<th>CHEMIST. N=169</th>
<th>PHYSICS N=241</th>
<th>ALL SCI. N=758</th>
<th>O-LEVEL N=74</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>34%</td>
<td>31%</td>
<td>38%</td>
<td>35%</td>
<td>47%</td>
</tr>
<tr>
<td>Comprehension</td>
<td>35%</td>
<td>39%</td>
<td>22%</td>
<td>32%</td>
<td>24%</td>
</tr>
<tr>
<td>Application</td>
<td>16%</td>
<td>18%</td>
<td>22%</td>
<td>18%</td>
<td>15%</td>
</tr>
<tr>
<td>Synthesis</td>
<td>7%</td>
<td>3%</td>
<td>1%</td>
<td>4%</td>
<td>13%</td>
</tr>
<tr>
<td>Psychomotor</td>
<td>7%</td>
<td>10%</td>
<td>16%</td>
<td>11%</td>
<td>0%</td>
</tr>
</tbody>
</table>

(ii) The New School-Leaving Examination in China

In China, less than 20% of the secondary school graduating class in a given year will continue on to higher education (Yang, 1991). Thus, in order to improve their students' chances of qualifying for a university place, schools begin to specialize early in those subjects to be taken in the college entrance examination. For students intending to major in science, the requisite subjects to be taken are political science, Chinese, mathematics, chemistry, physics, biology, and foreign languages. For future liberal arts majors, the subjects are political science, Chinese, mathematics, history, geography, and foreign languages.

There is no standardized school-leaving examination across China, so results on the college entrance examination have become the only indicator of school quality, and the force determining high school curricula (Yang, 1991). This situation has resulted in a great deal of frustration among the majority of learners who have no hope of passing the college entrance examination, which is being used to evaluate 95% of secondary school leavers in China.

In 1985, because of concerns with this system, a General High School Completion Test (GHSCT) was piloted in Shanghai and in four provinces. This new examination is state approved and is being administered by provincial testing organizations. The examination contains nine compulsory subjects—the subjects previously divided into science and liberal arts groupings. Assessment in laboratory skills is included for biology, chemistry, and physics. The wide-spread use of the examination beyond the pilot will be accompanied by newly defined content coverage across the curriculum.

When the program is widely implemented, the course of study for each subject will be completed over a one-, two-, or three-year period. Students will take the final examination in each subject as each course ends. By the third year of secondary school only three subjects will remain to be tested. Students who fail an examination will have an opportunity to retake that examination.

The level of the GHSCT is lower than the college entrance examination, since its purpose is to provide an opportunity for most students to obtain some form of completion certificate. With the widespread introduction of the GHSCT, the college examination will then be modified to include only three or four subjects.
Results from the pilot study have shown that participating teachers are demonstrating a greater concern for the education of the majority of their students, rather than just the college-bound few. Students are applying themselves to their studies in a more determined fashion. Thus, the general level of student performance is increasing.

The early division of students into science and nonscience streams has been abandoned in the test schools. Since the content and design of science courses in China is traditionally academic, the widespread implementation of the GCSE curriculum will raise many issues related to the content of science courses to be taken by the majority of students. The way in which "science for all" develops in China will be watched with great interest by many countries.

(iii) Environmental Education in the Caribbean

The standardized examinations of the Caribbean Examinations Council (CXC) have been used as a means of enforcing "top down" changes in the content of chemistry, physics, biology, and integrated science courses in the schools (Hill, 1990; Glasgow, 1987). The intent is to ensure that students in the English-speaking Caribbean develop a real appreciation for the local environment that will translate into caring, and responsible, environmental behavior.

Prior to reform, it was possible to pass the biology examination without answering a question on ecology. As a consequence, ecology tended to be left out of classroom instruction. In 1985 after the biology examination was revised, it became impossible to pass the examination without covering ecology. The syllabus for the chemistry examination now includes a section that focuses on local industries, and which involves students in an in-depth study of one industry. This section covers plant-site selection issues, economics, and waste management. Other sections of the chemistry syllabus also include environmental issues. The environment is considered both an organizing theme, and a focus of individual sections of the integrated science syllabus.

The examinations have both an external component (both written and/or practical), and a school-based, continuous assessment component. The school-based assessment for each examination takes place over a five-term period and, in addition to practical work, considers student attitudes to, and knowledge of, science and society issues (Hill, 1990; Glasgow, 1987). (One concern with continuous assessment is that it is difficult for the teacher to separate the formative and summative performance of students.)

(iv) Examination Feedback in Kenya

Until 1983, the Certificate of Primary Education (CPE) examination in Kenya was used as the main vehicle to select students for the limited number of secondary education places available. It was taken by students of between 13-15 years of age in science, mathematics, English, history, geography, and civics, after seven years of schooling. (It has now been replaced by a grade 8 leaving examination). There were both multiple-choice questions, and essay questions.

In the early 1970s, concerns arose that the CPE not only tested little more than factual recall, but that the facts were isolated, not integrated into any conceptual framework (Somerset, 1988, 1987). The knowledge tested was determined by the need to prepare (the few) for the next level of education, rather than (the majority) for life after formal schooling. From year to year, similar questions appeared on the examination, giving an advantage to students who spent time memorizing the facts likely to appear on the examination.
Reform of examination content took place between 1974 and 1979. The new examinations attempted to evaluate a wider range of cognitive skills, including a student's ability to see relationships among facts; determine causes and consequences; apply knowledge to new situations; and solve problems. There was also a focus on knowledge useful outside the classroom. For example, questions on nutrition, agriculture, health, and child care were included in the science examination (Somerset, 1988).

Most importantly, in an effort to use the CPE as more than a means of selecting students for secondary education, an examination feedback system was established to use the examination results to improve instruction—and, hence, student performance. A CPE newsletter was published annually, and sent to all schools, educational administrators, curriculum developers, and other concerned educators. The newsletter was used to: (i) explain changes in the examination content and the cognitive skills tested; and, (ii) provide teachers with a detailed analysis of which concepts were poorly understood by students, and suggest strategies to improve student understanding of these concepts.

In introducing this feedback mechanism, it was hoped that there would be a reduction of the performance gap among districts. (Schools from the urban districts outperformed schools in the poorer, rural districts.) Initially, however, the gap widened because teachers in the already successful districts had a greater opportunity to attend workshops and seminars explaining how the new system worked. Later, as the public in the low-achieving districts became aware of the situation, public pressure resulted in significant, and successful, efforts to improve performance through providing additional inservice support to teachers. Somerset (1988) concluded that:

"The results which were achieved within such a brief period are impressive evidence of the scope which exists—in Kenya and almost certainly in other developing countries—for improving the quality of basic education through strengthening professional and administrative support systems."

International Assessments of Educational Progress

For over 30 years, the International Association for the Evaluation of Educational Achievement (IEA) has been involved in international studies to compare the achievement of students in different countries over a range of subjects, and to explore the variables that contribute to observed differences in achievement. The Association is a non-governmental organization with membership from almost 40 institutions in 35 countries. While there have been, and still are, a range of technical difficulties associated with the comparability of data from different countries, the IEA surveys are at the "cutting-edge" of assessment practices.

There have been two international science studies conducted by IEA; the first study took place in the 1970s, the second in the 1980s. The first study found that gender was the greatest single factor affecting achievement in all countries participating, with male students out-performing females at ages 10, 14, and 18. The first study also determined that the time spent on learning was positively correlated with achievement.

Heyneman and Loxley (1983) have shown, using data from the First International Science Study as well as from other sources, that achievement in primary school science is much more strongly correlated with school- and teacher-quality variables in developing countries than in developed countries. Saha (1983) in his analysis of social structure and teacher effects on academic achievement reached the same conclusion.
The complete findings of the Second International Science Study are scheduled for release this fall, some five years after the end of the data-collection phase of this project, which occurred between 1983-1986. However, a number of preliminary overview reports have already been published, as well as several detailed country-specific reports (Soydhum, 1990a; Holbrook, 1990a, b; IEA, 1989, 1988).

The study examined the performance of three populations of students: 10-year-olds (usually grades 4 or 5); 14-year-olds (grades 8 or 9); and students in their final year of secondary education (17- to 19-year olds, grades 12 or 13). The first two populations answered multiple-choice questions covering science knowledge across the disciplines of chemistry, physics, biology, and earth science. The third population consisted of the science-stream students who were separately tested in biology, chemistry, and physics, and the non-science group who took a general science test. Students also provided information on their attitudes toward science, and their views on instruction.

The test questions were based on an "international consensus" curriculum, derived from an analysis of content items considered important to the participating countries. In addition, each country had an opportunity to add a number of other items to its own testing program.

Teachers and administrators provided information on the context within which student learning was taking place. Data were collected on: teacher pre- and inservice education; teacher characteristics and instructional habits; the conditions under which science is taught, including laboratory, equipment, and textbook concerns; school administrative structure; and the emphasis placed on different topics in the curriculum (a measure of the students' "opportunity-to-learn" a particular concept).

The usefulness of the study to the individual countries participating lies in the wealth of information that can be derived from these variables and their relationships to achievement, not from an absolute ranking compared to other nations. It would be naive, however, to underestimate the significance of ranking to politicians - and where there is political interest, resources for reform are more likely to be forthcoming. (The low relative performance of U.S. students is a case in point. The United States is now moving towards the definition of national "standards" for science learning from kindergarten to grade 12.)

Results from the study make very clear that the highest scoring students in the school-leaving population came from countries where there was a specialization in the sciences in the last two years of secondary school. Students from Hong Kong, Singapore, England, and Ghana showed the highest levels of achievement for biology, chemistry, and physics (IEA, 1989). Given the apparent success of the A-level system, the current debate on the future of A-levels in England clearly needs to be followed carefully. Students from Hungary performed very well in biology and physics, while students from Japan showed high achievement in chemistry and physics but not in biology. (It should be noted that there is an age range, and a grade-level range to consider when comparing country performances.)

However, the very countries that showed the highest achievement for the oldest students, were clearly much less successful in reaching the 10- and 14-year olds (see Table 4.5). Students from Japan and Hungary showed the highest levels of performance for the two younger populations, with Canada (English-speaking), the Netherlands, Korea, and Sweden also performing relatively well. Another general finding was that achievement levels for any given population within a country varied considerably from school to school with only a few exceptions. Norway, Sweden, Finland, and Japan showed a low between-school variance for the 14-year-old population, and Sweden and Japan showed no variance for the 8-year-old group (IEA, 1989). As in the First International Study, male students out-performed female students at all levels, with the differences in achievement increasing with age.
TABLE 4.5

Partial Results from the Second International Assessment (IEA, 1988)

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>10 YRS GR.4/5</th>
<th>14 YRS GR.8/9</th>
<th>GRADE 12/13 SCIENCE STREAM</th>
<th>NON SCI. STR.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10 YRS</td>
<td>14 YRS</td>
<td>BIOLOGY</td>
<td>CHEMIST</td>
</tr>
<tr>
<td></td>
<td>GR.4/5</td>
<td>GR.8/9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>9</td>
<td>10</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Canada (Eng.)</td>
<td>6</td>
<td>4</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>England</td>
<td>12</td>
<td>11</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Finland</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>13</td>
<td>16</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Hungary</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Italy</td>
<td>7</td>
<td>11</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Japan</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>Korea</td>
<td>1</td>
<td>7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Netherlands</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Norway</td>
<td>10</td>
<td>9</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Philippines</td>
<td>15</td>
<td>17</td>
<td>-</td>
<td>-</td>
</tr>
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<td>Poland</td>
<td>11</td>
<td>7</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Singapore</td>
<td>13</td>
<td>14</td>
<td>1</td>
<td>3</td>
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<td>Sweden</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Thailand</td>
<td>-</td>
<td>14</td>
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</tr>
<tr>
<td>USA</td>
<td>8</td>
<td>14</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td># Countries</td>
<td>15</td>
<td>17</td>
<td>13</td>
<td>13</td>
</tr>
</tbody>
</table>

Neither the first nor the second surveys involved the participation of many developing countries. Chile, India, Iran, and Thailand participated in the first survey. Thailand, Nigeria, Ghana, Indonesia, the Philippines, Korea, Papua New Guinea, and Singapore participated in the second survey.

The students from Chile, India, Iran, and Thailand did not demonstrate a high level of achievement on the First International Science Study. It has been argued that because of socioeconomic conditions, a lack of experience in test procedures, and the content of the curriculum, it is not appropriate to include developed and developing countries in the same survey. Keeves (1988) has pointed out that poverty conditions in developed countries (e.g., the United States and Italy) are also associated with lower achievement.
The results of the SISS seem to support the value of one survey. There is the strong performance of Ghanaian students in biology, chemistry, and physics; a significant improvement in the performance of Thai students in grade 9, compared to their performance on the first study; the strong showing of Korean 10-year-olds; and the low achievement levels of more than one developed country.

Thailand was the only developing country to participate in both studies and, thus, had an opportunity to evaluate progress in science achievement over a 15-year interval. As discussed in Chapter 1, the achievement of Thai students at the lower secondary level improved from a mean score of 35% on the first study, to 55% on the second (placing these students in the same score range as students from England, Italy, Singapore, the United States, and Hong Kong). The performance of Thai students at the upper secondary level also showed an improvement from the first to the second study, but the extent of that improvement was considered disappointing (Soydhurum, 1990a,b). Students in private schools had a much lower level of achievement than students in government schools. The difference in achievement between male and female students was not significant.

The Thai study produced a great deal of additional information that will help with future planning. For example, while most science teachers were well-prepared to enter teaching, a need was identified to improve teacher access to, and participation in, continuing education. Where inservice courses were available, their quality was debatable, with certificates awarded for completion rather than achievement (Soydhurum, 1990b). There was also the problem of teaching out-of-field.

Nigeria only participated in the primary science study. In addition to the international core test, students took a parallel, standardized national test based on the international core, but adapted to include local examples. The students' scores were higher on the locally adapted test, a finding that appears to support the position that IEA test items are not always culture free (Bajah, 1990). One unexpected finding from the Nigerian survey was that students from two areas considered "educationally disadvantaged," actually outperformed students from two areas considered "educationally advantaged." It was found that educational authorities in the former two jurisdictions had put more resources into their primary schools than the latter (Bajah, 1990).

To Bajah, the value of Nigerian participation in the SISS has been: the opportunity to gain experience in this type of survey work; the collection of base-line data to help future educational planning; and the boost to science education research in Nigeria that has resulted.

The Third International Mathematics and Science Study

The Third International Mathematics and Science Study (TIMSS) will measure students' achievements in mathematics and science worldwide, also gathering data on differences in curriculum content, and methods of instruction and assessment (IEA, 1991). Three age groups/levels of students will be included in the survey: age 9, 13, and 17/18 (school-leaving age). In the third group, there will be two cross-sectional studies of the achievement levels of both science and non-science stream students. The studies of the 9- and 13-year-olds may be conducted as either a cross-sectional or longitudinal study, as selected by each participating country (IEA, 1991a). The longitudinal study will span a year and include pre- and post-testing. Additional questionnaires to teachers and schools will establish the conditions under which science and mathematics learning is taking place in the classroom.

By summer 1991, some 39 countries had indicated that they would participate in TIMSS (IEA, 1991a). This number includes 25 countries from Europe; nine countries from Asia and the Pacific; three countries from North and Latin America; and Botswana and the former Soviet Union. Each country will establish its own national center comprised of members knowledgeable in mathematics and science curricula, sampling methodology, and questionnaire design. All centers will use the same sampling methods/designs as established
by the international organization. In each country, there will be a sampling of 150-300 classrooms per population sampled, with more than one classroom per population per school.

The international coordinating center for this study is at the University of British Columbia in Canada. The curriculum analysis framework is currently under development for both mathematics and science. Since the framework will be used to describe the generally expected learning outcomes for science and mathematics instruction in countries with very diverse curricula, it must be carefully reviewed to determine its wide applicability. There is no point in testing for knowledge that is not taught (i.e., not considered important) in the majority of nations participating.

At present, four categories of performance expectation have been identified for both science and mathematics. They are:

- "demonstrates factual knowledge;"
- performs standard procedures of the discipline;
- applies or extends the concepts, principles, and/or procedures of the discipline;
- reasons and makes connections" (IEA, 1991a).

It is intended that the test items cover a range of formats including multiple-choice and open-ended questions, and performance-based tasks completed at a series of workstations. There are also plans to include "task-based interviews with individuals or small groups of students." The performance-based items are likely to cause some problems in terms of ensuring equivalence from country-to-country of apparatus, materials, and the wording of test instructions.

The study will take place over a five-year period, beginning in 1990. Test instruments will be developed from 1991 to 1992, and data will be collected in 1993 and 1994. Data analysis will commence in 1994, with subsequent publication planned for 1995.

The lack of participation of African and Latin American countries in TIMSS is of concern. The lack of availability of a reliable, high-capacity computer to analyze survey data was identified by Bajah (1990) as one problem with Nigerian (and perhaps other developing country) participation in the SISS. He has suggested, in order to increase the participation of developing countries in future IEA surveys, that some provision be made to permit national coordinators from developing countries to use the computer facilities in a developed country. (In Africa only Nigeria and Ghana participated in the SISS. Both Zimbabwe and Tanzania dropped out during the study.) Bajah has also pointed out the difficulty of providing certain background data requested of SISS participants, when developing countries are just beginning to construct the necessary data banks.

There are a number of other inhibiting factors which are pertinent. Some developing countries may not have enough personnel with the wide expertise in science education research and assessment techniques that is needed to support participation in an international survey of this nature. The usefulness of participating in TIMSS may not be apparent to the decision-makers who must provide the necessary funding. Finally, even if the expertise and the will to participate are present, the money may not be available.

In April 1991, one possible way for more developing countries to participate in TIMSS was discussed at an UNESCO-sponsored regional meeting of IEA staff with educators from Venezuela, Chile, Columbia, Brazil, Argentina, Costa Rica, the Dominican Republic, Canada, and the United States. The suggestion was made that, in order to facilitate the participation of Latin American countries in TIMSS, a joint research team
from several of the countries present develop the policies, and share in organizing the survey for the region. This would reduce costs for staff, travel, translation, and data processing (IEA, 1991b).

Discussion

The assessment issue that is particularly pertinent to science instruction (i.e., how do you measure "hands-on" science) was discussed in Chapter 2 in more detail. It is perhaps appropriate to reemphasize that there are a number of unanswered questions about "hands-on" or performance-based assessment but that a great deal of research is underway to attempt to answer these concerns. (The U.S. 1994 National Assessment in Science will include a fairly high percentage of performance-based tasks -- one possibility that has been recommended by the planning committee developing the 1994 framework is that students' "science portfolios" be included in the assessment. A great deal can be learned from such an attempt.)

In both developed and developing countries, the standardized examination may control what happens in the classroom to an unhealthy degree. This situation can not be ignored, since science curriculum reform will fail if examination reform is not undertaken either at the same time, or prior to introduction of the new curriculum. The opportunity to use the examination to bring about reform is one possibility that has been successfully attempted in China, the Caribbean, and Kenya. Other systems could learn from these examples.

Participation in large-scale, cross-national studies, such as the upcoming TIMSS, could provide developing nations with the kind of data they need for informed implementation of educational change. The idea of a regional organization scheme for developing countries, as was discussed in Venezuela, has much merit, and should be supported by international donor agencies. When assessment is used for more than just student selection, it becomes the agent of meaningful change.
CHAPTER 5

WORLD BANK EXPERIENCE

Projects Supported

An analysis of World Bank support for secondary science activities was undertaken by reviewing the contents of Bank staff appraisal reports and project completion reports from 1963 to 1990. Project completion reports cover Bank activity for the period from 1963 to 1985, since the later projects have not yet been finally reviewed. From 1963 to 1990, some 105 World Bank projects have included one or more components that support improvements in secondary science education. Most of these components were a small part of a much larger project, usually in secondary education. Hence, this analysis is presented in terms of individual components, rather than as complete country projects.

As shown in Table 5.1, the Africa region accounted for some 35% of all the components identified. The EMENA region was next at 23% components, followed by LAC at 22%, and Asia at 20%. The periods of 1971-1975, and 1986-1990 were higher in activity than any other period reviewed, accounting for 25% and 26% of all components respectively. There has been an increase in support for teacher education programs over the past five years, but it is not clear if this represents a significant change in focus.

The majority of components (118) were related to the provision of "hardware" (i.e., texts, supplementary curricula materials, equipment, laboratory facilities, buildings, furniture, and equipment), with the construction and provision of laboratory facilities (61) being the main areas of support. A "science block" (8 components) is defined as a wing of laboratories attached to one school, while the term "science center" usually is used to describe a facility that serves a group of schools in a region. (The use of the term was not consistent in the reports reviewed.) Where science centers were provided (9 components), they typically were equipped with more complex, and expensive, instruments than found in individual schools.

A number of components were defined as teacher education programs. These programs included inservice education (25 components), preservice education (17), and training programs for the educators of the teachers (21). There was one project that included support for laboratory assistants, and two projects that trained school supervisors and advisory personnel. A more detailed breakdown of each of these components is given in Appendix C.

The names given to these components should not be misunderstood as implying support for teacher training courses, workshops, or seminars. While some teacher development activities were supported, many of the "software" components should really be reclassified as "hardware," since an analysis of the budgets shows that support of the category of "preservice teacher education" most often translated into building and equipping laboratories at teacher training institutes (see discussion below).

Financial Commitment

From 1963 to 1990, Bank loans in support of secondary science education amounted to $555 million (see Table 5.2). Of this amount, $21 million (4%) was committed during FY63-FY70; $39 million (16%) during FY71-FY75; $140 million (25%) during FY76-FY80; $223 million (40%) for FY81-FY85; and, $82 million (15%) for FY86-FY90. Thus, although a smaller number of components were supported in FY81-85 (see Table 5.1), the projects supported were larger and, presumably, more complex during this period than any other period analyzed.
TABLE 5.1
Incidence of Science Education Components, FY63-FY90
(PHREE review of education project SARs)

(a) Number of Components by Region

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>AFRICA</th>
<th>ASIA</th>
<th>EMENA</th>
<th>LAC</th>
<th>ALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher education</td>
<td>19</td>
<td>12</td>
<td>20</td>
<td>15</td>
<td>66</td>
</tr>
<tr>
<td>1. Inservice teacher ed.</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>9</td>
<td>25</td>
</tr>
<tr>
<td>2. Preservice teacher ed.</td>
<td>7</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>17</td>
</tr>
<tr>
<td>3. Training trainers</td>
<td>4</td>
<td>3</td>
<td>11</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>4. Training lab assts.</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>5. Training advisers/supervisers</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Other science</td>
<td>45</td>
<td>24</td>
<td>23</td>
<td>26</td>
<td>118</td>
</tr>
<tr>
<td>1. Curricula, materials</td>
<td>11</td>
<td>16</td>
<td>5</td>
<td>8</td>
<td>40</td>
</tr>
<tr>
<td>2. Science labs, rooms*</td>
<td>26</td>
<td>8</td>
<td>13</td>
<td>14</td>
<td>61</td>
</tr>
<tr>
<td>3. Science blocks</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>4. Science centers</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Total all components: number</td>
<td>64</td>
<td>36</td>
<td>43</td>
<td>41</td>
<td>184</td>
</tr>
<tr>
<td>percentage</td>
<td>34.8%</td>
<td>19.6%</td>
<td>23.4%</td>
<td>22.3%</td>
<td>100%</td>
</tr>
</tbody>
</table>

(b) Number of Components by Fiscal Years

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>63-70</th>
<th>71-75</th>
<th>76-80</th>
<th>81-85</th>
<th>86-90</th>
<th>ALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher education</td>
<td>12</td>
<td>12</td>
<td>10</td>
<td>12</td>
<td>20</td>
<td>66</td>
</tr>
<tr>
<td>1. Inservice teacher ed.</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>13</td>
<td>25</td>
</tr>
<tr>
<td>2. Preservice teacher ed.</td>
<td>4</td>
<td>7</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>3. Training trainers</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>6</td>
<td>4</td>
<td>21</td>
</tr>
<tr>
<td>4. Training lab assts.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>5. Training advisers/supervisors</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Other science</td>
<td>18</td>
<td>34</td>
<td>21</td>
<td>17</td>
<td>28</td>
<td>118</td>
</tr>
<tr>
<td>1. Curricula, mats.</td>
<td>4</td>
<td>9</td>
<td>4</td>
<td>5</td>
<td>18</td>
<td>40</td>
</tr>
<tr>
<td>2. Science labs, rooms*</td>
<td>12</td>
<td>20</td>
<td>10</td>
<td>11</td>
<td>8</td>
<td>61</td>
</tr>
<tr>
<td>3. Science blocks</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>4. Science centers</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Total all components: number</td>
<td>30</td>
<td>46</td>
<td>31</td>
<td>29</td>
<td>48</td>
<td>184</td>
</tr>
<tr>
<td>percentage</td>
<td>16.3%</td>
<td>25%</td>
<td>16.8%</td>
<td>15.8%</td>
<td>26.1%</td>
<td>100%</td>
</tr>
</tbody>
</table>
TABLE 5.2

Project Costs by Type of Component, FY63-FY90
(in US$ millions)

| COMPONENT                                                      | FY 63-70 | FY 71-75 | FY 76-80 | FY 81-85 | FY 86-90 | ALL    |
|                                                               |         |         |         |         |         |        |
| Teacher education                                            | 5       | 4       | 3       | 71      | 28      | 111    |
| 1. Inservice teachers ed.                                   | 0       | 2       | 0       | 2       | 7       | 11     |
| 2. Preservice teachers ed.                                  | 5       | 2       | 0       | 67      | 4       | 78     |
| 3. Training trainers                                        | 0       | 0       | 3       | 2       | 10      | 15     |
| 4. Training advisers/supervisors                             | 0       | 0       | 0       | 0       | 7       | 7      |
| Science education                                            | 16      | 85      | 137     | 152     | 54      | 444    |
| 1. Develop curricula & prototype equipment                  | 0       | 6       | 1       | 33      | 10      | 50     |
| 2. Science equipment/kits/instructional materials            | 0       | 1       | 30      | 44      | 14      | 89     |
| 3. Science labs/rooms                                       | 16      | 23      | 76      | 75      | 30      | 220    |
| 4. Science blocks                                           | 0       | 2       | 7       | 0       | 0       | 9      |
| 5. Science centers                                          | 0       | 53      | 23      | 0       | 0       | 76     |
| Total all: US$ millions                                     | 21      | 89      | 140     | 223     | 82      | 555    |
| percentage                                                  | 3.8%    | 16%     | 25.2%   | 40.2%   | 14.8%   | 100%   |

(PHREE Review of Education Projects SARs)

Table 5.3 gives a breakdown of project costs for each region by line items. This table makes clear that more money has been loaned to the Asia region ($198 million, 36%) than any other. The Africa region comes next with loans amounting to $148 million (27%); followed by LAC at $109 million (20%), and EMENA at $100 million (18%). What is especially interesting about this data is the small amount of funding for technical assistance (i.e., "people costs") across all regions. Only $69 million (12%) supported fellowships for teachers/teacher trainers and the provision of science educational experts. Of the total loaned, only $51 million (9%) supported continuing education programs for teachers/teacher trainers.

The extremely small amount of money that went to countries in Africa to support teacher fellowships is rather startling (only $1 million out of $148 million). This is an order of magnitude smaller than any other region. Table 5.4 shows the technical assistance budget component as a percentage of funds committed in each region. The LAC region has provided more support for technical assistance as a percentage of money loaned than any other region.
TABLE 5.3

Project Costs by Line Item by Region
(in US$ millions)

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>AFRICA</th>
<th>ASIA</th>
<th>EMENA</th>
<th>LAC</th>
<th>ALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Civil works</td>
<td>81</td>
<td>77</td>
<td>43</td>
<td>59</td>
<td>260</td>
</tr>
<tr>
<td>2. Furniture</td>
<td>16</td>
<td>9</td>
<td>2</td>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>3. Equipment</td>
<td>38</td>
<td>60</td>
<td>40</td>
<td>18</td>
<td>157</td>
</tr>
<tr>
<td>4. Technical assistance</td>
<td>7</td>
<td>26</td>
<td>14</td>
<td>22</td>
<td>69</td>
</tr>
<tr>
<td>Fellowships subtotal</td>
<td>1</td>
<td>20</td>
<td>10</td>
<td>20</td>
<td>51</td>
</tr>
<tr>
<td>Fellowships mixed</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Fellowships local/regional</td>
<td>0</td>
<td>16</td>
<td>0</td>
<td>15</td>
<td>31</td>
</tr>
<tr>
<td>Fellowships international</td>
<td>1</td>
<td>3</td>
<td>10</td>
<td>3</td>
<td>17</td>
</tr>
<tr>
<td>Expert subtotal</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>Experts local/regional</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Experts international</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>5. Operating costs</td>
<td>2</td>
<td>26</td>
<td>0</td>
<td>0</td>
<td>28</td>
</tr>
<tr>
<td>6. Other</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Total all: US$ millions</td>
<td>148</td>
<td>198</td>
<td>100</td>
<td>109</td>
<td>555</td>
</tr>
<tr>
<td>percentage</td>
<td>26.7%</td>
<td>35.7%</td>
<td>18.0%</td>
<td>19.6%</td>
<td>100%</td>
</tr>
</tbody>
</table>

(PHREE Review of Education Projects SARs)

TABLE 5.4

Technical Assistance Costs as Percentage of Each Region's Total

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>AFRICA</th>
<th>ASIA</th>
<th>EMENA</th>
<th>LAC</th>
<th>ALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fellowships</td>
<td>0.7%</td>
<td>10.1%</td>
<td>10.0%</td>
<td>18.3%</td>
<td>9.2%</td>
</tr>
<tr>
<td>Experts</td>
<td>4.1%</td>
<td>3.0%</td>
<td>4.0%</td>
<td>1.8%</td>
<td>3.2%</td>
</tr>
<tr>
<td>Total fellows + experts</td>
<td>4.7%</td>
<td>13.1%</td>
<td>14.0%</td>
<td>20.2</td>
<td>12.4%</td>
</tr>
</tbody>
</table>

(PHREE Review of Education Project SARs)

Teacher Training

As mentioned previously, there were a large number of "teacher education" projects supported (66 or 36% of components) by loans totalling $111 million (20% of total dollars). Yet the technical assistance costs are much lower than that. Another way to analyze this information is to scrutinize exactly what the "teacher
education" costs were spent on. As indicated previously most of these funds supported the construction of laboratory facilities, and the provision of equipment to be used in teacher pre- and inservice programs, not the actual programs themselves. Table 5.5 shows the percentage of funds designated for pre- and inservice teacher education that was actually spent on equipment and facilities, where this could readily be determined. (Note that this is in addition to the funds previously identified as supporting equipment and facilities.)

**TABLE 5.5**

The Hardware Component of Costs Classified as Teacher Training Support
(Expressed as percentage of funds expended on facilities and equipment)

<table>
<thead>
<tr>
<th>PRESERVICE</th>
<th>YEAR</th>
<th>HARDWARE</th>
<th>INSERVICE</th>
<th>YEAR</th>
<th>HARDWARE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sudan-1</td>
<td>1968</td>
<td>13%*</td>
<td>Malaysia-1</td>
<td>1972</td>
<td>38%</td>
</tr>
<tr>
<td>Korea-1</td>
<td>1969</td>
<td>100%</td>
<td>Mali-1</td>
<td>1973</td>
<td>0%</td>
</tr>
<tr>
<td>Guatemala-1</td>
<td>1969</td>
<td>21%</td>
<td>Peru-1</td>
<td>1974</td>
<td>0%</td>
</tr>
<tr>
<td>Kenya-2</td>
<td>1970</td>
<td>100%</td>
<td>Korea-6</td>
<td>1984</td>
<td>0%</td>
</tr>
<tr>
<td>Somalia-1</td>
<td>1971</td>
<td>0%</td>
<td>PNG-3</td>
<td>1985</td>
<td>100%</td>
</tr>
<tr>
<td>Liberia-1</td>
<td>1972</td>
<td>100%</td>
<td>Togo-2</td>
<td>1985</td>
<td>2%</td>
</tr>
<tr>
<td>Zaire-1</td>
<td>1972</td>
<td>36%</td>
<td>Portugal-4</td>
<td>1988</td>
<td>0%</td>
</tr>
<tr>
<td>Jordan-1</td>
<td>1972</td>
<td>23%</td>
<td>Burundi-4</td>
<td>1988</td>
<td>1%</td>
</tr>
<tr>
<td>Philippines-2</td>
<td>1973</td>
<td>53%</td>
<td>Maldives-1</td>
<td>1989</td>
<td>0%</td>
</tr>
<tr>
<td>Thailand-3</td>
<td>1973</td>
<td>0%</td>
<td>Tanzania-7</td>
<td>1990</td>
<td>0%</td>
</tr>
<tr>
<td>El Salvador-2</td>
<td>1974</td>
<td>17%</td>
<td>Turkey-6</td>
<td>1990</td>
<td>83%</td>
</tr>
<tr>
<td>Liberia-3</td>
<td>1977</td>
<td>100%</td>
<td>Indonesia-24</td>
<td>1990</td>
<td>50%</td>
</tr>
<tr>
<td>Egypt-3</td>
<td>1981</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malawi-4</td>
<td>1981</td>
<td>29%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morocco-5</td>
<td>1982</td>
<td>40%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>YAR-8</td>
<td>1987</td>
<td>34%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turkey-6</td>
<td>1990</td>
<td>45%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(PhREE Review of Education Projects)

To clarify Table 5.5, in the Korea-1 project 100% of the funds classified as supporting preservice teacher education were used to build facilities and/or provide equipment to teacher training facilities. None of the funds for the Malaysia-1 project were spent on facilities or equipment. In the Malaysia-1 project 38% of the funds for preservice education were used for buildings and equipment.
Of special interest in the majority of these projects is the provision of well-equipped laboratories/science centers and new instructional materials with apparently little attention being given to the training of teachers in the use of these new materials, or the use and maintenance of the equipment. As shown in Table 5.6, only 11% of the laboratory/materials projects from the Africa and LAC regions were identified as being accompanied by inservice education. For EMENA, the corresponding figure was 12%, and for the Asia region 29%.

**TABLE 5.6**

Number of Laboratories/Centers/Equipment/Materials  
(PHREE review of education project SARs)

(a) By Region

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>AFRICA</th>
<th>ASIA</th>
<th>EMENA</th>
<th>LAC</th>
<th>ALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provision of labs/centers/equipment/materials</td>
<td>47</td>
<td>21</td>
<td>26</td>
<td>19</td>
<td>113</td>
</tr>
<tr>
<td>Provision of complementary inservice training</td>
<td>5</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>Percentage with both components</td>
<td>11%</td>
<td>29%</td>
<td>12%</td>
<td>11%</td>
<td>14%</td>
</tr>
</tbody>
</table>

(b) By Fiscal Years

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>63-70</th>
<th>71-75</th>
<th>76-80</th>
<th>81-85</th>
<th>86-90</th>
<th>ALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provision of labs/centers/equipment/materials</td>
<td>19</td>
<td>26</td>
<td>22</td>
<td>19</td>
<td>27</td>
<td>113</td>
</tr>
<tr>
<td>Provision of complementary inservice training</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>7</td>
<td>16</td>
</tr>
<tr>
<td>Percentage with both components</td>
<td>5%</td>
<td>12%</td>
<td>5%</td>
<td>21%</td>
<td>26%</td>
<td>14%</td>
</tr>
</tbody>
</table>

What is not clear from many of the reports reviewed is the extent to which complementary teacher training is supported by either the government receiving the loan, or some other agency. A small number of reports do state that this did happen, but most give no clear indication. It can perhaps be inferred from the project outcome tables (found in Appendix C) that, in fact, teacher inservice education usually either did not take place, or was provided at some minimal level, if not actually supported within the Bank project. These tables make quite clear that one of the main problems associated with using the laboratories and equipment provided was that, in many projects, the teachers were not prepared to teach laboratory-based science.
Project Outcomes

In examining project outcomes as described in Bank project completion reports (see Appendix C), it is striking how few of these outcomes are expressed in terms of educational gains. Laboratories are either built or not built; they are well constructed or they are not; the equipment arrives or it does not arrive; projects meet budgets or they exceed budgets; work is completed on schedule or it is not. A project is rated as successful if it meets these kind of criteria; only rarely are educational outcomes such as teacher quality or student achievement even mentioned. It is not clear from the project completion reports if this focus is a result of the comparatively short time-span from project completion to evaluation -- educational outcomes tend to be observed over a longer period of time -- or if educational outcomes were considered somehow irrelevant, or unmeasureable (see Table 5.7).

When students are mentioned, it is usually in terms of enrollments in the science stream. Sometimes there are too many students to accommodate in the facilities provided, sometimes not enough. An increase in student enthusiasm for science may be mentioned as an outcome, but no indication is given as to how this gain was measured. Improvements in student achievement are sometimes mentioned, but rarely. Some quantitative feel for these outcomes is given in Table 5.7, where the most frequently mentioned outcomes for the projects indicated in Appendix C are compiled by region.

The outcomes listed are, of course, not the only outcomes discussed in the Project Completion Reports; they are the outcomes that appear most frequently for all regions. The number of project components analyzed to produce this data was 89. Of the outcomes/comments listed, there were 98 positive comments and 71 negative comments. The absence of a comment in any category is related to the different nature of the projects analyzed for each region: Africa region projects tended to focus on laboratories and equipment; Asia region projects tended to focus on teacher education or materials development; EMENA region projects analyzed included more equipment provision than laboratory construction; and LAC had a balance of types of components.

The difficulties encountered with projects supported in Africa are striking -- the ratio of positive to negative comments is almost 1:1. The probability of laboratories being constructed as planned is about 50/50. There are more comments related to maintenance problems with equipment in the Africa region than in all the other regions combined (10 mentions vs. 3). The lack of utilization of laboratories in this region is associated with the large number of reports of unqualified teachers -- again much greater than all the other regions combined (11 vs.4). Conversely, the number of mentions of "appropriate" teacher training for the African projects was 2 out of 38 components, compared to the aggregate from the other regions of 10 out of 51 components. Given the low level of financial support for teacher training in the region (see Tables 5.3 and 5.4) these results were predictable.

Issues Related to the Supply of Equipment and Consumables

Some of the problems associated with providing equipment and consumables (apart from the teacher training issue) are the same as those identified by Searle (1985) in her general operational review of textbooks; others differ because of the nature of equipment and consumables. These problems were:

(i) an underestimation of probable costs, especially related to the need to continually resupply consumables;

(ii) the absence of an organized delivery system for consumables;
TABLE 5.7

Project Outcomes by Region
(Phase Review of Evaluation Reports on Program Implementation)

<table>
<thead>
<tr>
<th>OUTCOME/COMMENT</th>
<th>AFRICA</th>
<th>ASIA</th>
<th>ENEMA</th>
<th>LAC</th>
<th>ALL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>*N=38</td>
<td>N=13</td>
<td>N=18</td>
<td>N=20</td>
<td>N=89</td>
</tr>
<tr>
<td>1. No. of positive outcomes cited</td>
<td>40</td>
<td>14</td>
<td>28</td>
<td>16</td>
<td>98</td>
</tr>
<tr>
<td>2. No. of negative outcomes cited</td>
<td>47</td>
<td>0</td>
<td>11</td>
<td>13</td>
<td>71</td>
</tr>
<tr>
<td>1. All labs/centers built as planned</td>
<td>12</td>
<td>5</td>
<td>8</td>
<td>3</td>
<td>28</td>
</tr>
<tr>
<td>2. Not all labs built as planned</td>
<td>10</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>3. Labs well utilized</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>4. Labs not well utilized</td>
<td>7</td>
<td>0</td>
<td>3</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>5. Labs overcrowded</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>6. Equipment delivered as planned</td>
<td>11</td>
<td>2</td>
<td>10</td>
<td>3</td>
<td>26</td>
</tr>
<tr>
<td>7. Equipment too complex</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>8. Equipment maintenance problems</td>
<td>10</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>9. Lack of consumables</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>1. Teachers well-qualified/improving</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>2. Teachers not well-qualified</td>
<td>11</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>3. Teacher training appropriate</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>4. Student enrollment increase</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>5. Better student achievement/motivation</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>6</td>
</tr>
</tbody>
</table>

*N = Number of components of projects (see Appendix C)

(iii) the preparation of equipment lists by people unfamiliar with the curriculum (and, apparently, the qualifications of the teachers);

(iv) the ordering of complex equipment (perhaps for reasons of status?) that cannot be used by students (or, sometimes, by teachers);

(v) the ordering of chemicals with little consideration for laboratory safety (e.g., many of the chemicals used in the old qualitative analysis scheme are now known to be carcinogens -- they may not legally be used by secondary-level students in most developed countries -- yet they are still being ordered by developing countries);

(vi) a lack of understanding about the need for continuing equipment maintenance; and,

(vi) the need to provide some form of environmental protection for certain equipment (e.g., protection from blowing sand, moisture, etc.).
Solving the procurement/distribution problems will include: (i) realizing the need for managerial competence and structure; (ii) developing a long-range plan to support the procurement and distribution systems for, at least, five years into the future -- this plan should be updated annually; (iii) using well-informed educators to draw up procurement lists -- items on these lists should be justified by associating them with curriculum objectives; (iv) requiring an "amount-of-use" estimate for all complex/expensive equipment; (v) developing procedures manuals for all distribution/ordering operations, with the inclusion of contingency plans for emergencies; (vi) providing training sessions for all fulfillment staff, especially the barely literate who are unable to follow a procedures manual; (vii) revising procurement and fulfillment procedures as experience is gained; and, (viii) on-the-job training for logistical support staff.

If no equipment maintenance support system is in place, one should be developed. This should also be undertaken with: (i) informed organizational planning; (ii) the identification of adequate financial resources to support the system for the foreseeable future; and, (iii) technician training and retraining.

The problems not addressed by these organizational solutions are educational in nature. There remains the need to provide workshops and courses for teachers to upgrade their understanding of the purposes of laboratory instruction, and to increase their familiarity with the equipment provided. Inferred from the data provided is a general lack of teacher understanding of safety issues; thus there is probably an ongoing need to provide workshops on laboratory safety, even in the absence of a new laboratory/equipment project.

Table 5.8 summarizes these recommendations for the three problem areas identified. For many (although not all) of the projects reviewed, the apparent underestimation of the complexity of the undertaking is striking -- there is a need for modern, deliberate management planning in order to ensure the success of these efforts. Otherwise it is difficult to escape the conclusion that time, effort, and money will not be well spent.

**TABLE 5.8**

<table>
<thead>
<tr>
<th>PROCUREMENT/DISTRIBUTION</th>
<th>MAINTENANCE</th>
<th>TEACHER SUPPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Begin with adequate financial resources</td>
<td>Begin with adequate financial resources</td>
<td>Begin with adequate financial resources</td>
</tr>
<tr>
<td>Formulate the organizational structure</td>
<td>Formalize the organizational structure</td>
<td>Develop a system to support teacher training</td>
</tr>
<tr>
<td>Standardize procedures</td>
<td>Standardize procedures</td>
<td>Tailor the program to the needs of differently qualified teachers</td>
</tr>
<tr>
<td>Adapt procedures as experience grows</td>
<td>Adapt procedures as experience grows</td>
<td>Adapt the program as experience grows</td>
</tr>
<tr>
<td>Provide ongoing staff training</td>
<td>Provide ongoing staff training</td>
<td>Provide training on an ongoing basis</td>
</tr>
<tr>
<td>Plan for the future</td>
<td>Plan for the future</td>
<td>Plan for the future</td>
</tr>
</tbody>
</table>
Examples of Specific Bank Projects

Four Bank projects were reviewed in greater detail, one from each of the operational regions. These projects illustrate the range of science education projects supported by Bank loans. (In Chapter 3, there is also a detailed discussion of the science teacher training component of a Bank-supported project in Indonesia.) This discussion will focus on the objectives and plan of action of the four projects. No budget analysis will be given, but complete budgets for these projects will be found in Appendix C. The projects are: (i) from Togo, a secondary science teacher training program that was a component of a larger general educational improvement project (Togo-II); (ii) from Korea, a comprehensive secondary science program that was a component of a larger science and technology education project that also included tertiary education (Korea-VI); (iii) from Turkey, a science teacher training program that is a part of a general education project (Turkey-VI); and (iv) from Brazil, the science education component of the current Brazilian Science Research and Training Project (FADCT-II).

(i) The Togo-II Project Science Education Component (SAR 5293-TO, 1985)

The Togo-II Educational Improvement Project was designed to:

1. Improve the quality of education at the primary school level by providing:
   - teacher inservice education to about 5,850 teachers through distance education, seminars, three-month courses at the primary teachers colleges.
   - refresher courses for inspectors and advisors.
   - low-cost textbooks to students.

2. Improve the quality of education at the lower secondary level by providing:
   - teacher inservice education to upgrade the skills of about 1,250 science and mathematics teachers through annual seminars and onservice support.
   - refresher courses for 21 inspectors and advisors.
   - 12 new science facilities, and upgrading 12 existing laboratories and workshops for teacher training and prototype equipment construction.
   - support to convert 262 classrooms in 234 schools into science rooms.
   - basic instructional materials and equipment.

3. Improve the management of education by assisting:
   - the state Educational Planning Division – in the planning and allocation of resources.
the state School Construction and Maintenance Division —
in planning school rehabilitation and preventative
maintenance.

the state Project Implementation Division — in strengthening
project preparation and implementation.

The total amount of the loan was $124 million. Detailed budget information is provided in Appendix
C. This discussion will focus on support for the secondary science program, but it is important to view the
context from which Bank support of secondary science education in Togo was actually provided.

The educational system in Togo is based on a primary cycle of six years, followed by a four-year lower
secondary cycle, and a three-year upper secondary cycle, after which students take the Baccalaureate examination.
Dropout rates, failures, and repetitions are high at the primary and lower secondary levels. (Of the group which
entered Grade 1 in 1981-82, 15% dropped out by Grade 2; only 44% of this same cohort reached Grade 6.
During the 1982-83 school year, 42% of students in grade 6 were repeaters; only 47% of this group passed the
lower secondary school entrance examination. Only 12% of this group will pass on to the upper secondary level.)

Only 16% of the mathematics and science teachers at the lower secondary level have professional
qualifications. A professionally trained teacher at this level is expected to have attended the Secondary Teacher
Training College of Atakpame, which offers a two-year course after the lower secondary cycle, leading to the
award of a teaching diploma.

The quality of mathematics and science teaching at this level is also low because the better students do
not choose to become secondary school teachers — they can work for higher pay in the private sector. Working
conditions are poor; there are no teaching materials for mathematics and science; textbooks are expensive and
scarce. The science curriculum is highly abstract, with little relevance to the lives of the students.

The program for teacher upgrading has consisted of a series of 10-day annual seminars, provided to
groups of 50/60 teachers, and offered about 20 times a year. During the seminars, teachers were encouraged
to place less focus on theory, and more on applications. The seminars have covered modern teaching methods;
the use of teacher demonstrations assisted by students; building simple equipment; ways of introducing local
applications into science classes; and using instructional guides.

The mathematics and science inspectors have also attended a 10-day annual seminar to help them
provide onservice support to the teachers. The Directorate of Teacher Training and Curriculum Development
has developed the instructional guides, and the designs for prototype equipment to be built at the workshops.
They have also provided training sessions for the most qualified of the teachers who will, in turn, provide
inservice support to their colleagues. The budget has provided for per diem and travel costs to support 238
manyears of local training, 57 manmonths of fellowsips (in educational financing and management), and 54
manmonths of specialist services (also in educational management).

The laboratory construction/upgrading efforts were described above. This component has included a
mechanism to determine future rehabilitation needs through ongoing surveys and supervision. The focus for the
equipment and materials has been on the simple and the local.

All inspectors, lower secondary school principals, and other administrative personnel have attended an
annual six-day seminar to learn how to collect the data necessary to evaluate the success of this program — there
were a number of survey instruments developed to measure change in teacher classroom performance through
classroom observations. Since the evaluation of this project will shortly be completed, it is inappropriate to
predict its results to date. However, it is impossibly difficult to start from such a low level, and achieve any kind of measurable success in such a short period of time.

**TABLE 5.9**

**Organization of Teacher/Inspector Training**

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>NO. TEACHERS</th>
<th>NO. SEMINARS/YR</th>
<th>NO. OF PARTICIPANTS/YR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspectors</td>
<td>-</td>
<td>1</td>
<td>21</td>
</tr>
<tr>
<td>Teachers of math and physics</td>
<td>510</td>
<td>21 x 2</td>
<td>510</td>
</tr>
<tr>
<td>Teachers of math and biology</td>
<td>500</td>
<td>21 x 2</td>
<td>500</td>
</tr>
<tr>
<td>Teachers of physics and biology</td>
<td>250</td>
<td>11 x 2</td>
<td>250</td>
</tr>
</tbody>
</table>

(ii) The Korea-VI Project Science Education Component (SAR No.4891-K0, 1984)

The Korea-VI Program for Science and Technology Education was developed to address perceived problems in the quality of science and technology education at both the secondary and tertiary levels of instruction. The objectives of the project are:

1. At the secondary level, to improve the quality of laboratory instruction by:
   - providing inservice training to some 3,600 science teachers to familiarize them with the methods and skills of laboratory instruction, and continuous assessment of practical work.
   - introducing new secondary science courses with a greater emphasis on practical work.
   - upgrading science facilities and equipment.
   - adjusting the college admissions procedures to reward student achievement in school, including experimental work.

2. At the undergraduate level, to improve the quality of instruction by:
   - increasing the supply, and improving the qualifications of, faculty members in science, science education, and engineering.
   - improving the laboratory facilities, and providing the equipment needed for effective teaching of undergraduates.
3. At the graduate level, to improve the quality and research capacity of higher education by:

- establishing accreditation committees under the aegis of the Korean Council for University Education to control the quality of undergraduate programs in science, and graduate programs in science and engineering.
- concentrating the resources for graduate science and engineering education in a few research-oriented universities and research institutes, fostering collaboration between universities and institutes.
- providing the laboratory facilities and equipment necessary for quality research.
- establishing a specialized center, the Korean National University of Teacher Education, within a network of colleges and education research institutes, to support graduate training and research in science education.
- developing a long-term plan for support of graduate training.
- strengthening the management structure and programs of the Korea Science and Engineering Foundation, which promotes and funds science and engineering research.

4. Ensure the continued supply of technically trained personnel by:

- providing improved career counselling to undergraduate students.
- monitoring student enrollments, and projecting future enrollments.
- conducting studies on manpower supply and demand.
- strengthening support for private educational institutions.

The total amount of the loan was $100 million; the actual loan was $96.5. This discussion will focus on those components related to secondary level science.

Korean students perform well on international standardized science achievement tests in the domain of science knowledge; their achievement has been lower on questions related to science skills. Through these tests it has been established that, compared to students from other countries who have stronger skills, Korean students were spending less time in the laboratory for a variety of reasons. Therefore, the focus of the secondary-level program was on improving school laboratory instruction.

While most Korean secondary science teachers have university degrees, in the past their training emphasized content and theory. From 1984-1988, this project provided training to 116,025 teachers, with a focus on laboratory skills (this number includes teachers attending more than one course). An additional 2,076
teachers received training outside Korea during the same period. Training was also provided for laboratory assistants, raising the numbers trained from 46 in 1984 to 543 in 1989. In addition, 40% more science teachers were recruited, dropping the student/teacher ratio from 23.8 to 22.4.

The Korea National University of Teacher Education opened in 1985 as a model institution, integrating preservice education, inservice education, and science education research. Graduate school enrollments have not met targets. Although government policies favor employment teachers with a graduate degree, job placement is difficult because there are many unemployed teachers.

At the beginning of this project, the level of laboratory availability was about 75% of requirements—limiting the access of students to equipment and laboratory time. By 1991, the laboratory availability ratio had risen to 80%, although not enough usable equipment had been acquired.

In 1987, the Ministry of Education commissioned the Korea Education Development Institute to study curriculum reform. The total reform period for textbook revision, equipment-list updating, teacher inserviceing, and curriculum implementation was extended into 1992. The original plan was to produce 140 experimental units to support a level of 20% laboratory instruction by 1988. The revision includes courses in chemistry, physics, biology, and earth science.

A Science Education Development Committee was established within the Ministry of Education. The Committee has completed an analysis of primary and secondary student science achievement, and collected data on all environmental factors known to contribute to this achievement. This data has been used to produce a science education development plan, which starts from the existing system, and defines eight developmental tasks to be accomplished in order to reach the ideal system.

These tasks are: (i) reforming science education and establishing a monitoring system; (ii) supporting research and development and international research in science education; (iii) supporting teacher training institutions; (iv) upgrading the quality and morale of all science educators; (v) improving the environmental conditions under which science is taught; (vi) promoting general conditions for science instruction; (vii) promoting programs which are related to science education (nonformal science education?); and, (viii) establishing an assessment system for science education.

It is not entirely clear from the project completion report what is meant by each of these tasks. What is clear is that the reform of science education in Korea is both a high priority, and a long-term effort, which will be undertaken from a basis of knowledge and careful planning.

(iii) Turkey-VI National Education Development Project (SAR No. 8328-TU, 1990)

The Turkey-IV National Education Development Project will focus on three issues pertinent to both primary and secondary education, namely student achievement, educational efficiency, and organizational management.

The specific objectives of the project are to:

1. Increase the level of student achievement to a level approaching the average of OECD countries through:
   0 reviewing curriculum policy and development, and reviewing and revising curricula. (This includes new programs in computer literacy.)
producing and field testing new textbooks and instructional materials based on the new curricula.

- improving the distribution of textbooks and materials.

- conducting numerous research and evaluation activities to define student achievement, and the relevant school-based variables, with the purpose of using this information as the basis for future planning.

2. Improve the quality and relevance of teacher education to a level consistent with accepted practice in OECD countries by:

- using a competitive, peer-reviewed proposal system to select 10 of 17 university faculties of education to upgrade their teacher training facilities, equipment, and resources in at least three subjects (e.g., mathematics, science, social studies).

- supporting inservice teacher education through all means available including the use of "master teachers" (cascade workshops); existing faculties and education and primary teachers college; distance learning using TV and correspondence courses.

- establishing educational resource centers to serve as multi-purpose extensions of the Ministry of Education, charged with responsibility for teacher training, materials development, program assessment, and clearing-house functions.

3. Improve the management and program administration of the Ministry of Education by:

- supporting organizational restructuring, management training, and strategic planning.

- expanding and improving information management, and research and development activities.

The total amount of the loan is $90.2 million. Detailed budget information is found in Appendix C. This project does not have a distinct secondary science component, but secondary science will, of course, be one of the areas supported within this project.

In Turkey, general education consists of primary school (grades 1-5), middle school (grades 6-8), and secondary school (grades 9-11). There are 1,300 general secondary schools with an enrollment of about 650,000 students (93% of secondary enrollment); 98 Anatolian schools (combined middle and general high schools which teach mathematics and science in either English, French, or German) with around 45,000 students; and seven Science Secondary Schools for the talented and gifted, which enroll about 1,600 students. Entrance into the latter two categories of school involves passing highly competitive entrance examinations. Not only are the students select, but so are the teachers.
Secondary science teacher training is either a four-year program (until 1984 it was three years) offered by a university faculty of education, and leading to a bachelor's degree combining subject specialty and pedagogy, or a degree awarded jointly by the faculties of science and education. It is also possible to take a four-year science degree, followed by a fifth year for teacher education courses. For employment, teachers must also pass a national teacher certification examination.

Inservice teacher education, which is considered essential, is the responsibility of the Ministry of Education, although the universities may also provide courses. A range of opportunities currently exist including programs to upgrade from the old three-year to the new four-year requirement; residential summer programs; distance learning courses; and local and overseas fellowships.

The inservice component of the National Educational Development project will help support an existing program requiring all teachers to participate in a refresher course at least once every five years. This support will include a needs assessment, as well as design of programs to meet these needs (see list of objectives).

The research and development component of this project will include an evaluation of the extent to which school laboratories are currently used for instruction, and an inventory of science equipment and supplies. There will also be a determination of whether or not to equip the middle and secondary schools to support teacher demonstrations, rather than practical work for students.

Since this project does not have a distinct component to support science education, it will not be discussed in any more detail. It is presented as a fairly typical example of many Bank projects, which support science education as part of general education, but are not categorized as specifically supporting science.

(iv) Brazil - Science Research and Training (PADCT-II) (SAR No. 8811-BR, 1990)

This project is similar to Korea-VI in that its purpose is to support the development of scientifically and technologically trained personnel, and to enhance research capacity. The main aims of the project are to consolidate and extend the gains made in human resource development and institutional reform through the initial project (PADCT-I). Recognizing that the development of scientific and technologically trained personnel begins long before the university, the project supports science education as one of its 12 subcomponents. The other 11 subcomponents are in the areas of biotechnology; chemistry and chemical engineering; geosciences and mineral technology; instrumentation; science planning and management; science equipment maintenance; science consumables; science information; basic industrial technology; new materials; and environmental science.

The science education subcomponent of PADCT-II extends the efforts of the first project, which involved inservice teacher training; curriculum and materials development; establishing graduate-level programs in science education; and, most importantly, establishing a network of educators and scientists working together to improve the quality of primary and secondary education in Brazil. The first project supported many small programs, with a view to identifying talent and ideas from all over the country. The second project will concentrate on supporting fewer activities, expanding the more successful of the projects piloted in PADCT-I; as well as on strengthening the networks of scientists and educators committed to innovative science education.

The PADCT-II science education subcomponent will provided competitive, peer-reviewed grants to support:

1. Research and studies in science education --
   1. 10 consolidated groups with research experience
- 116 -

2. Innovative preservice teacher education programs involving curriculum development, teaching methods, cooperative education, exchange programs —
   - 20 emerging groups with some qualified researchers
   - 100 training courses for primary and secondary education
   - 15 specialization courses
   - 7 graduate-level programs

3. Development of continuous teacher inservice education programs with the participation of local and state systems —
   - 10 continuous programs to reach 35,000 teachers per year
   - 3 distance teaching programs to reach 100,000 teachers

4. Five interdisciplinary science education centers

5. Production and dissemination of educational materials —
   - 9 groups with educational materials capacity
   - 10 centers to serve as lending clearing-houses
   - 5 books "of relevance"
   - 5 bulletins describing important PADCT-financed projects
   - 2 TV-series for primary and secondary school teachers
   - TV commercials in support of science

6. Dissemination of science knowledge and awareness to a wider audience —
   - 6 science centers (for the general public)
   - 15 science fairs
   - 5 science or mathematics olympiads
   - 18 meetings and symposia
   - publication of 5 periodicals

7. High-level human resource development —
   - 80 masters and doctorates overseas
   - 180 masters and doctorates in Brazil
15 post-doctorates overseas
50 short courses overseas
50 visits to centers of excellence
100 instances of support for participation in overseas events

8. Programs under CAPES (Coordination for Advanced Training of Higher Education Personnel, the Brazilian agency with overall responsibility for this project)
- Evaluation, including Brazilian participation in TIMSS
- Competition for monographs
- Awards for distinguished teaching
- Competitions for innovative materials

Clearly the scope of this particular project is very different from the other three programs evaluated—for that matter it is more comprehensive than most of the other Bank projects reviewed. PADCT-II began in 1991 for a five-year period.

**TABLE 5.10**

**PADCT-II Science Education Budget by Objectives**
(Bank Report No.8811-BR)

<table>
<thead>
<tr>
<th>BUDGET BY OBJECTIVES</th>
<th>US$M</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Support research and studies in science education</td>
<td>1.6</td>
</tr>
<tr>
<td>2. Preservice education of primary and secondary teachers</td>
<td>13.1</td>
</tr>
<tr>
<td>3. Strengthen inservice education</td>
<td>5.5</td>
</tr>
<tr>
<td>4. Strengthen five interdisciplinary centers</td>
<td>0.0</td>
</tr>
<tr>
<td>5. Produce and disseminate educational materials</td>
<td>4.5</td>
</tr>
<tr>
<td>6. Disseminate science knowledge to the general public</td>
<td>4.6</td>
</tr>
<tr>
<td>7. Human resource development</td>
<td>11.7</td>
</tr>
<tr>
<td>8. Programs under CAPES</td>
<td>1.7</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>42.7</strong></td>
</tr>
</tbody>
</table>

Problems associated with secondary science education in Brazil are similar to the problems described for other countries. According to Ministry of Education officials the courses are highly theoretical, and the books, on which many teachers depend, are of low quality. The teachers are poorly prepared by the universities and teach in an expository manner. Laboratory instruction is inadequate (Marques, 1986). Communication between the universities and educational administrators is very poor, cooperation a rarity. Communication between the faculties of science and education within a university needs to be greatly improved, as does communication between science education centers at different universities.
Thus, the science education subcomponent is structured to promote cooperation between scientists and educators, between the federal and state governments, and between local governments and industry. Many types of institutions are eligible for grants under this program, including state and local governments, colleges and universities, and professional societies.

Coordination of effort for both PADCT-I and PADCT-II is within the jurisdiction of CAPES, a department within the federal Science and Technology secretariat. There is a technical group for each subprogram responsible for planning, supervision, and evaluation. The group meets at least three times a year to issue requests-for-proposals (RFPs) to meet each subprogram's objectives. RFPs receive as wide a distribution as possible. Each subprogram has its own advisory committee, charged with assessing and making recommendations on the proposals received. All proposals are first reviewed by ad hoc consultants who prepare an assessment of proposals received for consideration by the advisory committee. The advisory committee makes its selections, which can be overruled by the technical group if deemed appropriate. The science education advisory committee consists of scientists, science educators, and classroom teachers. The technical group mirrors the composition of the advisory committee.

Proposals are selected for funding using a point system, and specific criteria: technical feasibility of the proposal plan; responsiveness to the RFP; qualifications and ability of the project principals; adequacy of the budget; and, evaluation component. Programs which provide matching funds from other sources (e.g., state programs) are especially encouraged, as are programs which involve cooperation among different groups.

One feature of this subprogram that was not found in the other three projects is support for nonformal science activities. The project goals recognize that secondary science education is not just important for future scientists, but also future citizens. There is also recognition of the need for public support of science education. Unlike most other programs reviewed, the Brazilian project also includes support for environmental education.

Summary

These four projects are either recently completed, or recently initiated, programs, with very different problems to solve. As with other Bank projects in science education, they are all a component of a larger project, which focuses on either the improvement of general education in a country, or on the development of science and technology capacity. Interestingly enough, no programs were identified as a component of a larger project related to health, nutrition, agriculture, or the environment. They may exist, but they were not found. Given the shift toward science for all, the Bank should begin to consider how support for science education could, in some way, be integrated into these other kinds of programs.

The Togolese program is significant for its emphasis on teacher-training seminars, to be accompanied by an evaluation of actual teacher classroom behaviors. It is modest compared with the other programs, but realistic. The focus of the Korean program on informed planning over an extended period is also realistic. The Turkey program includes a range of strategies to improve teacher qualifications, including the decentralization of training through "cascade" workshops. Finally, the Brazilian project also attempts a decentralization of capability, as part of an ambitious systemic overhaul.
CHAPTER 6
STRATEGIES FOR CHANGE

The preceding chapters have summarized the current status of the main factors that collectively determine the effectiveness of science education in any country: the content of the curriculum; the conditions for instruction; the training of the teacher; and the nature of the student assessment process. Also included has been a discussion of the new expectations for science education at the secondary level as expressed through the “Science for All” movement. This chapter develops a matrix of goals and strategies that are relevant to any practical efforts to accomplish sustainable reform of science education.

As Young (1990) pointed out in his analysis for the World Bank of the donor role in science and technology education, there is no one “quick fix” that will result in the desired outcomes. A selection of interventions will be necessary, with the exact mixture defined only after considering country-specific goals and constraints. If science education research in developed and developing countries has produced one clear message it is this – no one intervention works in all places at all times. A second important message is – never underestimate the complexity of the task attempted.

The Matrix

Three areas of intervention are explored:

1. Curriculum and instruction
2. Teacher quality and status
3. Assessment of learning and teaching.

For each area of intervention, commonly expressed goals are defined; and for each goal multiple possible strategies are listed, and briefly discussed where appropriate. The preceding chapters give a more complete description of many of these strategies, with specific examples from many different countries. Since any meaningful reform is likely to involve coordinated change in all three areas of intervention, strategies relevant to one area are cross-referenced to goals in the other areas where applicable. Not included in this treatment is a cost/benefit analysis – a subject for a subsequent, and lengthier, study.

It should be noted that this matrix is not an attempt to imply that, for reform to take place, all of these goals must be adopted, and all strategies relevant to each goal must be implemented. It is merely an attempt to clarify some of the options available. That being said, there is also the factor of time sequencing to be considered when implementing strategies. Certain interventions should take place concurrently (e.g., teacher training and curriculum reform). Other interventions may be sequential (e.g., establishing the need for curriculum reform must precede any attempt to actually begin the reform process). Finally, these are only a few of the possibilities.
Summary of Goals

AREA OF INTERVENTION: 1. CURRICULUM AND INSTRUCTION

GOAL A. To establish a recognition of the need for curriculum reform
GOAL B. To revitalize existing science curricula at the secondary level
GOAL C. To optimize the use and improve the quality of laboratory instruction
GOAL D. To reform the science curriculum at the secondary level
GOAL E. To improve teacher subject matter competence and classroom practice

AREA OF INTERVENTION: 2. TEACHER QUALITY AND STATUS

GOAL A. To attract better qualified students into the teaching profession
GOAL B. To improve the quality of teacher preservice education
GOAL C. To provide for teacher continuing education
GOAL D. To reduce teacher resistance to change in the classroom

AREA OF INTERVENTION: 3. ASSESSMENT OF TEACHING AND LEARNING

GOAL A. To recognize the assessment process as a means of improving teaching and learning in school science
GOAL B. To improve teacher understanding of the purposes of assessment
GOAL C. To reform the standardized examination system

Goals and Strategies

AREA OF INTERVENTION: 1. CURRICULUM AND INSTRUCTION

GOAL A. To establish a recognition of the need for curriculum reform

(No major curriculum reform should be attempted if the need for reform is not clearly recognized by the "stakeholders" in the reform process. These stakeholders could include: ministry officials; inspectors; school principals; teachers; members of examination councils; university professors in faculties of education and science; professors at teacher training colleges; employers in the government sector and private industry; politicians; parents; and students!)

STRATEGIES:

(i) Collect data defining the current status of science education in the target country, if possible in relationship to similar countries in the region, in order to help establish a need. Link the need for curriculum change with identifiable country-wide issues, e.g., health, nutrition, agricultural practices, etc. Then continue with the following strategies.

(ii) Organize an overseas study tour for influential decision-makers to give them first-hand exposure to the process of reform in other countries. Include other countries in the same region. Build in a "report back" mechanism to crystallize commitment.
Encourage the development of a policy document defining specific measurable goals for science education reform to be accomplished in a given period of time. This document must include input from those individuals expected to implement the reform, as well as from the political decision makers (see Area 2, Goal D).

Build a consensus on the need for change among not only those in the policy-making establishment, but all those impacted upon by any proposed reform (see Area 2, Goal D). The consensus process should include those stakeholders mentioned above. Of special importance are the teachers and students.

Use the broadcast and print media to promote the need for reform to the general public.

GOAL B. To revitalize existing science curricula at the secondary level

STRATEGIES:

(i) Redefine the national syllabus. Develop new texts; initially perhaps introduce them as "supplementary material" as a means of catalyzing further change. A case can made that any change is likely to improve a situation that has remained in stasis for a number of years — at least temporarily (the Hawthorne effect).

(ii) Develop and distribute programmed lessons/teaching kits on a range of locally relevant topics to classroom teachers. This effort should also include workshops to train the teachers in use of this kind of material (see Area 2, Goal C). During these workshops teachers need to be clearly shown how this material links with the existing syllabus. Attention also must be paid to teacher morale, especially if the introduction of kits is viewed as an effort to circumvent the teacher by the teacher.

(iii) Develop and broadcast TV and radio programs on science concepts; local, national, and international research developments; and career opportunities in science that may not be the traditionally identified opportunities (see Area 2, Goal C).

(iv) Introduce low-cost equipment into the secondary school classroom (see Area 1, Goal C). Some groundwork will be needed to counteract the image of such equipment as inferior, and incapable of enhancing the science learning of students. Teachers must also receive instruction on the use and maintenance of this equipment.

(v) Organize field trips to locations where science can be seen in service to the community. Locations might include industries, hospitals, farms, radio and TV stations, water-treatment facilities, etc. (see Area 2, Goal C).
(vi) Organize national inter-school science competitions including science fairs, radio and TV challenge programs, etc. These could be part of the activities of school- or community-based science clubs. The science olympiads held on all continents are successful examples of this approach.

(vii) Use science museums, science resource centers, zoological gardens, and national parks to develop out-reach programs for students, teachers, and parents.

GOAL C. To optimize the use and improve the quality of laboratory instruction

STRATEGIES:

(i) Provide in-service training for teachers, emphasizing laboratory skills and pedagogy (see Area 2, Goal C; Area 3, Goal B). This could include, for example, training in the use of microscale chemistry equipment.

(ii) Build and equip new laboratories for secondary science instruction. Care should be taken to equip a laboratory in a simple fashion—the one-time per year use of demonstration equipment can not be cost-justified. Note that a modern laboratory should provide for safe instruction and include (for chemistry) a fume hood. Also, many of the chemicals commonly found in school laboratories 20 years ago are now known to pose significant health risks. They should not be permitted in a secondary school laboratory in any country. (This should only take place in conjunction with the previous strategy.)

(iii) Establish regional resource centers to produce low-cost equipment. This strategy should include teacher training to build and maintain prototype equipment. Mass production of equipment should utilize local industrial enterprise where possible. Much equipment, even of a fairly sophisticated electronic nature, can be built in sheltered workshops.

(iv) Develop self-contained, easily maintained science kits. Teachers need to be trained in the use of these kits. Build in a reliable resupply network.

(v) Develop a mobile laboratory staffed by trained, travelling resource teachers to bring hands-on science, and science demonstrations to the students. Use this resource to teach local staff laboratory management and maintenance skills.

(vi) Provide workshops to teach the teachers to train upper secondary school students as laboratory technicians, prepared to give demonstrations to the younger students, and coach them in laboratory skills.

(vii) Take the students to science centers and science museums to see demonstrations and experience hands-on science.

(viii) Recognizing the costs associated with laboratory-based instruction, especially at the upper secondary level, adopt a policy supporting the establishment of "sixth-form colleges" emphasizing science. Concentrate financial resources for
laboratory instruction in these facilities. Establish policies to ensure that there is equality of access to these institutions for rural/poor students.

GOAL D. To reform the science curriculum at the secondary level

(This should NOT be attempted unless strategies to implement Area 1, Goal A, have been successful.)

STRATEGIES:

(i) Reform the standardized examination to reflect new content and desired competencies – curriculum reform will follow! This reform probably means a change of both content and style of the examination, reflecting new curriculum objectives.

(ii) Working within existing organizational structures, adopt an already developed curriculum from another country, with modifications for the local situation. Direct adoption without adaptation should NOT be attempted (see Area 2, Goals C and D).

(iii) Working within existing organizational structures, develop a new curriculum for the lower and upper secondary school embracing the 'science for all' philosophy, within the context of clearly articulated national needs (see Chapter 1).

(iv) Working within existing organizational structures, develop an "accelerated" science curriculum for the scientifically talented and gifted at the secondary school level (see Chapter 1). This selection process must be carefully designed for equity. Students who are good but not brilliant belong with the majority of the students.

(v) Establish a free-standing, peer-reviewed proposal mechanism within the target country to award a curriculum-development contract to the local non-profit organization(s) which submit(s) the most realistic proposal. Engage the efforts of the professional teacher organizations where they exist.

GOAL E. To improve teacher subject matter competence and classroom practice

STRATEGIES:

(See Area 2, Goals B and C.) Note: No curriculum reform should be attempted unless the reform includes a strong, and sustained, effort of teacher continuing education.
AREA OF INTERVENTION: 2. TEACHER QUALITY AND STATUS.

GOAL A. To attract better qualified students into the teaching profession

(i) Recognize the professionalism of teachers by paying a higher base wage. (This may be unrealistic as a suggestion, but if teachers have to hold on to multiple jobs in order to survive financially, then it is even more unrealistic to expect the "brightest and the best" to be attracted to teaching.)

(ii) Recognize the professionalism of teachers by instituting a system to award a Master Teacher's Certificate to teachers passing a national certifying examination. Couple this certificate with either higher pay, or a one-time cash bonus.

(iii) Institute a national award for excellence in science teaching. This may be monetary, involve support of further study, travel-study overseas, or any other means of recognition that a culture finds appropriate.

(iv) Provide funds to support the travel of Master Teachers to national and international conferences.

(v) Explore a system of non-cash perquisites for science teachers including free housing, subsidized schooling for immediate family, etc. This could also include subsidizing subscriptions to overseas science teachers' journals — a small, but significant, way to bring about change.

GOAL B. To improve the quality of teacher preservice education in subject matter and pedagogy

STRATEGIES:

(i) Institute a system to train the teacher educators to at least the level of a master's degree in science education. This education must include both modern science and pedagogy. Make it mandatory that no teacher educator receives a permanent appointment, or a promotion, until he/she meets nationally defined standards of excellence, or provide sufficient incentives that teachers decide to participate.

(ii) Give the teacher trainers a wider exposure to alternative teacher training systems by supporting national and international study tours to other institutions, not as a means of providing them with one "magic" answer, but to introduce them to other ways of solving common problems.

(iii) Develop mechanisms to encourage cooperation between faculties of education and science, and/or between universities and teacher training colleges, leading to reform of teacher preservice education.
(iv) Support the upgrading of library facilities in teacher training institutes and faculties. This might include exploring the reliability and relative costs of providing key literature in microfiche or CD-ROM formats.

(v) Upgrade the laboratory facilities at the teacher training establishments. Also, provide training and ideas for use of the equipment that is available in the schools, or provide designs and advice for local production of equipment/use of local materials in school science.

GOAL C: To provide for teacher continual education in both subject matter and pedagogy

STRATEGIES:

(i) Provide short courses for science teachers in both science content and innovations in teaching methodology, using a "carrot and stick" approach to increase enrollment in such courses. Establish local training opportunities where the universities train Master Teachers, who in turn train other teachers.

(ii) Offer correspondence and other courses to teachers through the broadcast media (an "open university" system). Pay for teachers to take these courses.

(iii) Use the Master Teacher designation and perquisites to reward all forms of teacher participation in continuing education.

(iv) Provide regular inservice workshops during the school year, with continuing education credits awarded for attendance. Attach this credit system to promotion prospects.

(v) Provide funds to local science teachers' organizations to support the publication of newsletters/journals for, and by, science teachers. Make these publications available to all teachers.

(vi) Get tertiary science institutions and local science-based industries involved in a dialog with teachers on instructional needs and how they can be met. Also involve the parent organizations.

GOAL D. To reduce teacher resistance to change in the classroom

(However this is attempted, it should always be considered as a limiting factor of sustainable reform.)

STRATEGIES:

(i) Include teachers as an integral component of all school science reform efforts (see Area 1, Goal A).

(ii) Provide government subsidies to support the activities of professional associations of science teachers.
AREA OF INTERVENTION: 3. ASSESSMENT OF TEACHING AND LEARNING

GOAL A. To recognize the assessment process as a means of improving the quality of teaching and learning in science classes

STRATEGIES

(i) Encourage the cross-country sharing of experience in the use of national assessment as more than a screening device. This might include support of sector conferences, workshops, and symposia.

(ii) Support participation of the country in international evaluations such as the upcoming Third International Mathematics and Science Study.

(iii) Stimulate a national dialog related to the purposes of assessment that involves the tertiary institutions, employers, teachers, and administrators, and the national press.

(iv) Develop assessment practices that provide feedback to teachers on the specific strengths and weaknesses of their students. Help teachers use this knowledge by providing workshop support on remediation techniques.

GOAL B. To improve teacher understanding of the purposes of classroom assessment and translate this knowledge into classroom practice

STRATEGIES:

(i) Increase the emphasis given to various components and methods of evaluation in preservice teacher training programs (see Area 2, Goals B and C).

(ii) Develop model teaching/learning/evaluation packages for distribution to teachers to serve as exemplars of how assessment can be used to enhance teaching and learning. Provide workshops on the interpretation and further expansion of this material.

(iii) Develop national test-banks of exemplary, pre-tested items that are culture neutral or culture supportive. A range of styles of question (multiple-choice, grid questions, essay questions, etc.) should be included. Make this test bank widely available, if appropriate on computer disc or CD-ROM as well as in print.

(iv) Help teachers develop strategies to operate with large classes. (It is understood to be an unrealistic suggestion to reduce class size in many countries. However, it should be noted that in large classes it is impossible for teachers to give attention to individual students. Hence, the use of the test to address the specific learning difficulties of each student is something of a moot point — if not a completely naive expectation! If teachers are expected to teach higher-level thinking skills and hands-on science then class size is a significant factor — and must, somehow, be addressed.)
GOAL C. To reform the standardized examination system

STRATEGIES:

(i) Rewrite the existing examinations to include more questions that test for higher-level thinking skills; that test for concept understanding rather than vocabulary; and emphasize depth rather than breadth of knowledge.

(ii) Include a classroom-based performance component to the standardized examination (see Area 2, Goals B and C; Area 3, Goal B). Give teachers instruction in continuous assessment techniques.

(iii) Support the adoption of a dual examination system that includes both achievement and aptitude tests.

Planning for Systemic Reform

The speed of reform, and the sequence of tasks to be accomplished to achieve reform depend on system-specific variables. Most importantly, there must be the political recognition that change is needed, and the political will to sustain what, for all systems, will be a long-term process. The costs of reform are obviously a factor that will have impact on the level of ambition of the reforms proposed, and the time taken to accomplish reform. However, the premise of the following discussion is that, eventually, all systems, regardless of financial condition, will have to initiate systemic reform if the slogan "science for all" is to be a genuine national goal, and not mere posturing.

As stated frequently throughout this document, the teacher is the limiting determinant of reform. It is completely unrealistic to introduce even the most carefully structured of curricula, using the most well-developed of textbooks, if attempts are not made to improve the subject-matter knowledge, and classroom behavior of the science teacher. Thus it is proposed that systemic reform begin by first considering the continuing education needs of teachers in the classroom. These needs will only be really apparent if there is a base-line study conducted to determine the actual educational background of science teachers in a given country, together with a quantitative assessment of teacher access to, and participation in, inservice education.

The teachers may have subject-matter competence (particularly at the upper secondary level), but lack the skills needed to convey this knowledge to an intellectually diverse group of students. In this case, it will be possible to introduce new content together with ways of new delivery of content. If the teachers do not have a sound grasp of their discipline, or are expected to teach out-of-discipline, then there will need to be an initial concentration on science content. The new pedagogy can not be effectively implemented by teachers who lack confidence in their own subject matter competence (see Figure 6.1).

It is clearly futile to prepare teachers who graduate already in need of significant retraining. Thus, the teacher preservice education component must also be reorganized, bearing in mind the weaknesses already identified in the knowledge and performance of teachers who have graduated from the existing system. Few countries have developed an effective mechanism to link inservice and preservice education in a meaningful fashion. Yet this link needs to be established.
Figure 6.1

Paths to Reform

1. CHOICE OF REFORM

ASSUMPTIONS: CHOICE DETERMINED BY TEACHER QUALITY

A) IF TEACHERS KNOW SUBJECT MATTER

STEP 1

NEW PEDAGOGY NEW CONTENT

GOAL

NEW PEDAGOGY NEW CONTENT

B) IF TEACHERS SCIENCE KNOWLEDGE IS POOR

STEP 1

NEW CONTENT

STEP 2

NEW PEDAGOGY

GOAL

NEW PEDAGOGY NEW CONTENT
Figure 6.1 (continued)

2. SEQUENCE OF REFORM

1. TEACHER
   CONTINUING
   EDUCATION
   ONGOING

2. TEACHER
   PRESERVICE
   EDUCATION

3. EXAM REFORM

4. MATERIALS
   DEVELOPMENT
   ONGOING

ASSUMPTIONS: EXAMINATION DRIVES SYSTEM

GOAL: IMPLEMENTATION OF NEW CONTENT/NEW PEDAGOGY CURRICULUM
Changing the content and manner of teacher education, whether preservice or inservice, is, of course, linked to the curriculum — what is a teacher expected to teach, and to what level of complexity. Thus, the curriculum redefinition and materials development phases of reform must begin almost concurrently with the initiation of the teacher improvement activities, and must interact with these activities in an ongoing fashion. It is most common to find curriculum reform leading teacher reform rather than the other way around. The model of reform discussed in this report suggests reversing the accepted practice because, all too often, reform never quite gets around to examining the role of the teachers in implementing the reform.

Where systems are driven by the examination, then curriculum redesign and assessment must occur concurrently, and in-phase with each other. It may be possible to allow the examination to lead the new curriculum, but not the converse (see Chapter 4).

Finally, it should again be reemphasized that the process of systemic reform to support science for all is an ongoing process. While specific goals can be met, at a given moment in time, there will always remain the need to provide continuing education to teachers, and to redefine the curriculum as our understanding of the natural world evolves, together with our appreciation of how best to convey this knowledge to young minds. There is always the danger that the reformers of today, once they have institutionalized their reforms, will become the reactionaries of tomorrow. Systemic reform of science education should always be structured to permit adaptation based on experience, and the realities of a rapidly changing world.
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World Bank Confidential Documents (Selected)


APPENDIX A

NON-FORMAL SCIENCE EDUCATION

Students learn about science in and out of the classroom. The school itself may provide a range of enrichment opportunities to encourage students to become more involved with science. These activities may include school science clubs, environmental programs, science fair participation, and field trips of various kinds. Outside the school situation, many communities offer science programs to students and other members of the public through local museums, science centers, national parks, and zoological and botanical gardens. These types of programs have the potential of reaching a large number of students and their parents (see Table A.1). There are also radio and television programs on science topics, and magazines and journals popularizing science.

This appendix will examine several activities that exemplify the range of non-formal science education opportunities: (i) the International Olympiad Movement; (ii) JETS of Zambia; (iii) out-of-school science in China; and (iv) the Heureka Science Museum in Finland.

(i) The International Science Olympiad Movement

If "hands-on" science is problematic in the regular classroom, project work related to student participation in local, regional, and national science fairs and competitions appears to be thriving in many countries. There is also a great deal of interest in science "olympiads" — "out-of-school" programs that involve high school students in competitive practical and theoretical examinations within their own country, and internationally.

In 1959, the first International Mathematical Olympiad (IMO) was held in Romania involving eight-member student teams from Bulgaria, Czechoslovakia, Hungary, the German Democratic Republic, Poland, and Romania. By 1988, 49 countries participated in the competition held in Australia, with an additional nine countries sending observers (O'Halloran, 1989). The official languages of the 29th IMO were English, French, Spanish, German, Russian, Arabic, and Chinese. Participants came from all continents: Europe (24 countries), Asia (12 countries), North and Latin America (13), Oceania (2), and Africa (3).

The first International Physics Olympiad (IPhO) took place in Warsaw in 1967, and the first International Chemistry Olympiad (IChO) was held in Czechoslovakia the following year. Like the IMO, both competitions were initiated by Eastern European nations, and both have grown steadily in participation ever since. The IPhO now involves around 30 countries from five continents, while the IChO typically hosts from 25 to 30 countries each year (Gorzkowski, 1989; Petrovic, 1989). (The International Olympiads are each held annually in a different country.) In the past several years, two additional competitions have been established for biology and informatics. The international governance of each of these competitions has been somewhat amorphous, but all are now under the aegis of the UNESCO Division of Science, Technical and Environmental Education in Paris (Pokrovsky, 1989).

There are a number of national and regional offshoots of these activities. For example, there are the Arab Gulf Science Olympiads which have been attended, at various times, by Kuwait, Bahrain, the United Arab Emirates, Saudi Arabia, Qatar, Oman, and Iraq (Shagalia, 1989). The first Arab Gulf Mathematics Olympiad was held in Kuwait in 1988; the first Arab Gulf Physics Olympiad was held in 1989. Kuwait, in addition to participating in the IMO, IPhO, and IChO, holds national olympiads for secondary school students in mathematics, physics, chemistry, biology, and geology.
TABLE A.1
Science in Non-formal Education: Museums, Science Centers, Zoos
(UNESCO, 1990)

<table>
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<tr>
<th>COUNTRY REPORTED</th>
<th>NAT HIST MUSEUMS</th>
<th>SCI+ TECH MUSEUMS</th>
<th>GENERAL MUSEUMS</th>
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</table>

Key: NAT HIST - Natural history/natural science museums; SCI+TECH - Science and technology museums, science centers, planetaria; GENERAL MUSEUMS - Mixed collections; VIS - Visitors/year; m - million; k - thousand
In Venezuela, the Centro Nacional para el Mejoramiento de la Enseñanza de la Ciencia (CENAMEC) is responsible for organizing national chemistry and mathematics olympiads. The Mathematics Olympiads for middle school students began in the 1970s to help promote an interest in mathematics among students, teachers, and the general public, and to encourage mathematical problem solving among students (Rada, 1986). Hundreds of thousands of students have competed in the national program; Venezuelan students have also participated in the International Mathematics Olympiad. The Venezuelan Chemistry Olympiad was first held in 1983, with similar objectives to the Mathematics Olympiad. The program involves student competitions, the training of both students and teachers, organizing visits to chemical plants in Venezuela, and running chemical "games."

JETS of Zambia organized the first African Subregional Science Olympiads in August 1990 in Lusaka. The participants were Zambia and Botswana, with Nigeria sending observers.

All of these programs, regardless of the country or science involved, share similar goals and methods of selecting and preparing students. Participating countries use these competitions to: help recognize scientifically talented and gifted students; identify national weaknesses in coverage of subject matter; encourage students to strive for excellence in science and mathematics; promote science to the general public; and test students' understanding of science in the international arena. Students who participate nationally may be selected via a series of competitive examinations, through performance on science fair projects, or even just by teacher recommendations. Successful students are usually further screened via a national examination to identify the team to compete internationally. Most countries coach their teams for varying lengths of time before the international competition.

The growth of the movement is one indicator of its success. Most countries seem to believe that they have benefited in some fashion from their participation, although there are some complaints about "over-competitiveness" internationally. For many, the real benefits result from the enthusiasm and achievements of the hundreds of thousands of students who never reach the final international competitions.

(ii) JETS of Zambia

The JETS (Junior Engineers Technicians and Scientists) program in Zambia was formed in 1968, under the jurisdiction of the Science Inspectorate of the Ministry of General Education Youth and Sport. Its National Executive Committee is usually chaired by the Dean of Engineering from the University of Zambia; Committee members include representatives from the teacher training colleges, teacher associations, and the National Council of Scientific Research, as well as Ministry officials (Chibesakunda, 1989). The aims of the organization are:

- To popularize science and technology among secondary and primary pupils.
- To help secondary school pupils get a better foundation to meet the increasing demands of science and engineering in technical colleges and universities.
- To give our youth an opportunity to learn and apply scientific principles in the design and construction of technical projects.
- To help students learn methods of how to conduct research.
- To help students in discovering and appraising their own abilities, aptitudes, and interests.
To make our youth be aware of opportunities for careers in engineering and science and related technical fields in the public and private sectors of our commercial and industrial life" (Chibeskunda, 1989).

JETS supports science clubs and student projects in primary and secondary schools; runs science fairs and olympiads at the local, regional, and national levels; provides science career information to students; runs workshops for club organizers, laboratory technicians, and students; and produces low-cost laboratory equipment. Each year, students from more than 300 secondary schools and 100 primary schools participate in provincial and national science fairs run by JETS of Zambia. Students write the questions for the school quizzes that are used to select the competitors in the regional fairs. Winners at the regional level are entered in the national competition. National prizewinners enter international science fairs, and attend the Nobel Prize ceremonies each year. A great deal of media attention is given to the national competitors.

JETS staff includes a full-time secretary within the Ministry, 11 regional organizers or coordinators. Each regional coordinator is responsible for the organization of schools within his/her region. At the school level, each club is run by the students, with science teachers from the school serving as advisors.

(iii) Out-of-School Science in China

There are many out-of-school science activities available to students in China (Liyuan, 1989; UNESCO, 1984). The National Leading Group for Youngsters’ Scientific Activities (NLGYSA), a consortium of government, science, and political organizations established in 1981, plays a coordinating role for such efforts at the local, provincial, and regional levels both by establishing policies and organizing activities. Various activities are also organized for students by science teachers and principals, by professional societies, and by the students themselves. In 1983, the China Association of Instructors for Youngsters Science Activities was established to run programs, conduct research, improve the level of education of out-of-school science instructors, and serve as a liaison with government officials (UNESCO, 1984).

Out-of-school science activities may be located in schools after the regular school day has ended, in science centers, and especially in “children’s palaces.” Activities offered include science camps and clubs; science fairs and competitions; lectures and exhibitions; field trips to science centers, museums, and botanical and zoological institutions; visits to research institutions; career awareness seminars; and project work of various kinds (Liyuan, 1989; UNESCO, 1984). Students can also engage in hands-on science activities through environmental investigations including monitoring acid rain, noise pollution, and air quality; planting trees, and tending birds, etc. (Zhai, 1989).

Many popular science magazines and journals are available nationwide, as well as radio and television science programming. There are also national exhibitions of student creations and inventions, and science fair projects. During the annual “Love for Science Month” primary and secondary students focus on expanding their knowledge of science (UNESCO, 1984). This may involve project work, writing a paper, reading a book, or attending a science film.

The out-of-school science activities available to students in China have a very different character from much of the science that is taught in Chinese secondary schools (Thulstrup, 1991; Liyuan, 1989). School science in China tends to be traditionally academic, with little recognition of science/technology/society interactions. Out-of-school science in China is quite the opposite; Liyuan (1989) has suggested that the vitality of nonformal science in China is a reaction to the nature of formal education, and may, in fact, eventually contribute to changes within the schools.
(iv) The Heureka Science Center in Finland

Heureka, the Finnish Science Center, which opened in 1989, includes a permanent exhibition room, room for temporary exhibits, a planetarium, an auditorium and a restaurant. There is also a nearby science park. The purpose of the Center is to promote science literacy by providing intellectually stimulating and aesthetically pleasing displays, demonstrations, and programs for students, teachers, parents, and members of the general public.

Visits to the Center may be self-guided, or conducted by trained Heureka guides. When students visit the center as part of a museum group, they first receive an orientation from their teachers to prepare them for the experience. The Center has developed teachers' support materials that include slides, videos, proposed learning objectives, and background information on the exhibits at the Center (Hautamaki, 1989). Once at the museum, the students may participate in either an exploration of the Center directed by the guides, who will identify a specific series of activities for the students; or, the students may undertake less structured, independent activities working in groups. The Center recommends that all such tours be discussed at school afterwards, to permit the sharing and consolidation of knowledge.

Summary

There are a range of out-of-class, out-of-school science activities available to students in many parts of the world. International competitions seem to have the same kind of impact as international assessments in that both stimulate interest in student achievement in science. The value of these competitions lies in the impact they have on the vast majority of students who will never make a national team. The early rounds of competition in olympiads, fairs, and talent searches involve the participation of hundreds of thousands of students — maybe even millions. These programs tend to be visible in the community, and to generate a great deal of interest in science among the general public — and the political establishment.

Student/teacher clubs such as JETS of Zambia give both groups an opportunity to develop a more interactive, question-asking relationship than may be possible in the classroom, given the typically didactic style of many teachers. Student-run clubs provide an additional bonus in that they give students a chance to acquire both organizational and leadership skills. Science museums and science centers are also important ways of conveying the wonder and excitement of science to students and their parents. While the opportunity to enrich a sterile curriculum through out-of-school science has much value, it is, however, no substitute for meaningful change in the classroom.
APPENDIX B

ENVIRONMENTAL ISSUES

The Nature of Environmental Education

Environmental science is not a single discipline but an integration of basic and applied sciences, including engineering and technology, with subjects such as sociology, economics, political science, and ethics. It is both descriptive of the total relationship between man and the environment, and prescriptive in that it attempts to define and solve problems resulting from this interaction. It is the set of human knowledge that is most relevant to the task of promoting sustainable development. It is quantitative in nature but based on a value system that recognizes the fragility and uniqueness of life on this planet (Baez, 1987).

Environmental education is the life-long process through which individuals and communities gain an understanding of their relationship to, and impact upon, the environment through the acquisition of relevant concepts and factual knowledge, technical skills, responsible attitudes, and real world experiences.

- It is interdisciplinary, with a foundation built upon a clear understanding of scientific principles.
- It involves the teaching of problem recognition and definition, as well as problem-solving. Thus, the development of decision-making capabilities, with all the associated constraints and ambiguities, is an essential component of environmental education.
- It is relevant to all students, not just those who are interested in a career in environmental studies.
- It brings the classroom into the community, and vice versa. It continues beyond the classroom through adult education.
- It has developed from an ethical position related to conservatorship of the land. Hence, it involves making judgements based on personal and community values (Baez et al., 1987).

Environmental Education in the Formal Education System

As indicated in Chapter 1, environmental education is undergoing a repositioning within the school curriculum that reflects today's awareness of the importance of building responsible attitudes toward the environment upon a firm foundation of accurate scientific knowledge. Man's use of the products of science and technology has contributed to many of the environmental problems threatening life on this planet. However, these problems will only be solved by men and women who understand the scientific principles of ecology, a science based on biology, chemistry, and physics.

Adherence to the traditionally defined disciplines of biology, chemistry, and physics is reinforced by the need of students to pass the standardized examinations. The curriculum is overcrowded already, so it is most unlikely that room will be made for a new course focussing on the environment. An "across the curriculum approach" may be the only way to ensure that environmental knowledge becomes a part of basic education.
At present, at the primary level, there is often a discrete course entitled either environmental studies or environmental science, depending on the balance of the course content. At this level, the teaching of environmental topics is also found in integrated science, general science, natural studies, health, agricultural studies, civics, geography, and social studies.

The most appropriate teaching materials for primary-level students focus on the students' own environment, using local examples and resources for illustration. There is research evidence that "teaching through the local environment" does promote a greater environmental awareness than more traditional approaches (Baez et al., 1987).

In secondary schools, environmental issues are found in a number of science courses including general science, integrated science, earth science, chemistry, physics, and biology (see Figure 1.2). The trend toward teaching integrated science, and the science/technology/society (STS) movement are reinforcing the tendency to include environmental issues across the curriculum (see Table 1.5). Environmental themes are often used as the organizing focus for integrated science courses. It is a rare STS course that does not include environmental issues.

New courses in the traditional disciplines are also reinforcing the legitimacy of environmental education. These new courses often introduce environmental issues in order to illustrate the utility and relevance of science to all students. Alternatively, some new science courses begin with a definition of the issues, and then demonstrate that students "need to know" science in order to solve problems associated with the issues. Not only do these type of courses cover environmental topics, but they share a common approach to instruction. They emphasize decision-making, the accessibility of science to all, and student-driven learning. The role of the teacher of these type of courses is often described as that of a "facilitator" or "manager" of learning; the "chalk and talk" approach to instruction is deemphasized as much as possible.

At the tertiary level, various aspects of environmental science may be introduced in biology, chemistry, or engineering courses in particular, or in an inter-disciplinary context. There is a need to include more environmentally related topics in the education of the technical professional. There is, however, a debate as to whether this integration should occur at the undergraduate or graduate levels. It is argued that it is important for scientists and engineers first to achieve a high level of expertise in their chosen disciplines before an in-depth study of the related environmental issues. Only with specialized knowledge are they able to contribute in a meaningful fashion to cross-disciplinary decision-making (Knamiller, 1987).

Problems Associated with Environmental Science in the Schools

One very pervasive problem in teaching environmental science is that few science teachers, in any part of the world, are very comfortable teaching in an inter- or multi-disciplinary context (Chisman, 1990). Many are poorly prepared in their own specialty (see also Chapter 3). Expecting teachers to demonstrate knowledge expertise in several subjects in one lesson is unrealistic given their current knowledge base.

Apart from the issue of the teacher's content knowledge, there is also the reality that many science teachers are unfamiliar or uncomfortable with the teaching behaviors and strategies commonly used in the STS/environmental science classroom. The need to provide extended inservice education to science teachers is largely unmet (see also Chapter 3).

The teacher preparation issue becomes even more of a problem when there is a lack of field-tested environmental teaching materials relevant to the local situation. Environmental education is most effective when it involves locally significant issues (Knamiller, 1987). Most teachers do not have the time, even if they have the
expertise, to develop such materials. Since most developing countries have a nationally defined curriculum, the teachers may be actively discouraged from even attempting to write their own materials. There is a need for specialized books, magazines, and audio-visual aids, but a lack of funds to make them available.

Another problem is the lack of coordination of environmental topics across disciplines, which results in fragmentation, omission, and/or duplication of topics. In upper secondary schools, where the traditional science subjects may be taught only as electives, those students who are most likely to become community leaders — whether or not they continue their formal education — may not develop a comprehensive view of the totality of environmental science. There is a need for much better in-school coordination of topics.

Non-formal Environmental Education

Formal education is not a prerequisite for environmentally conscious behavior, which may be a part of the sensitivity and folk-knowledge of a given culture. Where such an awareness exists, it should be exploited through the ways in which formal and nonformal environmental education are structured for that culture.

Conversely, cultural factors may play a negative role in promoting environmental awareness. People may be unable to participate effectively in public decision-making related to environmental issues because of problems of information transfer and acceptance.

Non-formal environmental education, for both adults and students, includes the activities of science, nature, and environmental clubs; displays and lectures at museums, science centers, nature parks, zoos, and botanical gardens; development of environmental awareness among the public through the use of the print and broadcast media; and, inclusion of environmental topics in adult literacy programs, and agricultural extension activities (see also Appendix A). Regrettably, there is a lack of trained leaders to plan and implement community-based environmental programs (Baez, et al., 1987). The broadcast and print media and press have begun to play an important role in the wide dissemination of environmental information, and the shaping of environmentally responsible attitudes. Non-governmental agencies, including professional teachers' associations, also have a great deal to contribute by bringing environmental education before the public. These groups, as well as local operations of multi-national corporations, should be encouraged to participate in a more meaningful fashion to public environmental education.

Two Case Studies

The following two programs are examples of environmental education in action within the community. The first is the Baltic Sea Project, which involves the Baltic nations; the second is a community-based science program from the Philippines.

(i) The Baltic Sea Project

The Baltic Sea Project is a multi-national, environmental school-based program which aims to:

- arouse young people's interest in environmental issues and environmental protection;
- develop their sense of responsibility for [the] environment; and,
provide them with tools by which [to] influence their own environment* (Yrjonsuuri, 1989).

The project, which is a collaborative effort of countries located around the Baltic Sea (Finland, Denmark, Sweden, Germany, Poland, USSR), is a joint activity of UNESCO's Associated Schools Project and International Network for Information in Science and Technology Education (INISTE). The project involves the development of a network of schools from Baltic nations, to promote a cross-national, cross-discipline study by students of the environmental status of the Baltic Sea. Students are collecting and compiling relevant environmental data; teaching materials are being developed; and teachers are receiving appropriate inservice training (UNESCO Associated Schools Project, 1990).

Students are adopting forests and lakes; studying dunes and coastal protection; exploring ways to measure and prevent pollution of rivers; cleaning up beaches; monitoring the flow of pollutants into the Baltic Sea; conducting physico-chemical analyses of seawater; evaluating the impact of human recreational use on coastal waterways; studying ecosystems; etc.

This project is only one of the many cross-national environmental programs being supported by UNESCO with similar objectives in other regions. There is also a Mediterranean Project, a Blue Danube Project, a Saharan Project, and a project in Asia. All are components of the UNESCO Associated Schools Project.

(ii) Community-based Science in the Philippines

The Science Education Center of the University of the Philippines has been organizing rural community-based science education programs since 1977. As farming and fishing are the main occupations in rural areas of the Philippines, the programs have focused on science knowledge of use to farmers and fishers. The most comprehensive of their programs was located in the fishing village of San Salvador. The aims of the program were to:

*Extend the reach of science education from the school to the home and community thereby providing closer links between learning in the school and learning at home and in the community;

Enrich the home environment of the elementary school pupils by involving parents in some practical and meaningful science-related activities;

Enrich the study of science at the elementary school level through meaningful home, family and community activities;

Use learning situations to encourage individual or family productivity; and,

Raise the level of scientific consciousness in the individual, family, and community* (Talisayon, 1986).

A needs and resources assessment of the community was first conducted prior to designing the program. This involved surveying parents and community leaders, interviewing officials, and reviewing the history, education, and economics of the region. The information collected also included collecting data on community health resources, plant and animal life in the locale, and skills found within the community.
The learning program involved running seminars and workshops on fishing methods, fishing equipment, maintenance of pump engines, communicable diseases, maternal and child welfare, nutrition, etc. A garden of medicinal herbs was planted. Community members learned to construct water-sealed toilets and desalinization units. The school curriculum was adapted to permit the infusion of community-based science activities for the students into the regular classroom. Reading centers were provided with relevant brochures and booklets. The science educators involved received specialized training to enhance their effectiveness.

The benefits of the program, as reported by community leaders, were improved health and sanitation, greater economic productivity, and the growth of self-reliance within the group (Talisayon, 1986).

Summary

Environmental education is a life-long educational process that involves both youth and adults, in both formal and non-formal educational settings. The constraints that apply to second-wave science education reform, are the same as those inhibiting environmental education (see Chapters 1, 2, 3, 4). The new science programs with both their change in content, and their new methods of delivery, are looking more and more like the vehicle through which environmental education will become an established part of the curriculum. Science educators and environmentalists would be well-advised to work together to achieve common goals (see Figure B.1).

Figure B.1

Ways to Deliver Environmental and Science Education

<table>
<thead>
<tr>
<th>FORMAL EDUCATION</th>
<th>NONFORMAL ED.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>YOUTH</strong></td>
<td></td>
</tr>
<tr>
<td>school science</td>
<td>science clubs, fairs</td>
</tr>
<tr>
<td></td>
<td>parks, zoos, nature centers,</td>
</tr>
<tr>
<td></td>
<td>museums, radio and TV</td>
</tr>
<tr>
<td></td>
<td>programs, etc.</td>
</tr>
<tr>
<td><strong>ADULT</strong></td>
<td></td>
</tr>
<tr>
<td>continuing education</td>
<td>science clubs, parks, fairs, zoos,</td>
</tr>
<tr>
<td>extension programs</td>
<td>nature centers, museums, radio</td>
</tr>
<tr>
<td></td>
<td>and TV programs, etc.</td>
</tr>
</tbody>
</table>
## TABLE C.1

Science Education Sub-components, FY63-FY90
(PhREE Review of Education Project SARs, August, 1991)

<table>
<thead>
<tr>
<th>SUB-COMPONENT</th>
<th>AFRICA</th>
<th>ASIA</th>
<th>EMENA</th>
<th>LAC</th>
<th>ALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumables incl. chemicals</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Secondary science equipment</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Science lab equipment</td>
<td>4</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Science prototype equipment</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Science kits</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Science rooms</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Science laboratories</td>
<td>20</td>
<td>6</td>
<td>10</td>
<td>13</td>
<td>49</td>
</tr>
<tr>
<td>Science centers</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Science block construction</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Instructional materials</td>
<td>6</td>
<td>14</td>
<td>3</td>
<td>6</td>
<td>29</td>
</tr>
<tr>
<td>Science curriculum development</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Inservice teacher training</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>19</td>
</tr>
<tr>
<td>Preservice teacher training</td>
<td>8</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>Maintenance of equip. training</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Science workshops</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Teacher training fellowships</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Teacher training support</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Training teacher trainers</td>
<td>4</td>
<td>3</td>
<td>11</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>Teacher training consultants</td>
<td>1</td>
<td>3</td>
<td>7</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>Lab asst. component</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Provision of experts</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>Provision of fellowships</td>
<td>2</td>
<td>3</td>
<td>9</td>
<td>6</td>
<td>20</td>
</tr>
<tr>
<td>Science educator specialists</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Training of advisors/supers.</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>All subcomponents</td>
<td>88</td>
<td>52</td>
<td>70</td>
<td>58</td>
<td>268</td>
</tr>
</tbody>
</table>

Note: This table is an expansion in detail of Table 5.1. Hence, there are more "sub-components" listed in Table C.1 than "components" in Table 5.1.
<table>
<thead>
<tr>
<th>PROJECT</th>
<th>COMPONENT</th>
<th>OUTCOMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Botswana-3</td>
<td>Science block</td>
<td>All labs built &amp; equipped. Results not assessed.</td>
</tr>
<tr>
<td>Burkina Faso-1</td>
<td>Science labs</td>
<td>Only 5 of 18 labs built because of cost issues—not well used because of lack of teacher training. No improvement in teaching observed.</td>
</tr>
<tr>
<td>Cameroons-1</td>
<td>Science labs</td>
<td>All construction, equipment, &amp; furniture provided &amp; suitable. No review of impact of labs/equipment on instruction.</td>
</tr>
<tr>
<td>Congo-1</td>
<td>Science labs</td>
<td>Labs provided &amp; suitable. Students more interested in science, more curious, enthusiastic.</td>
</tr>
<tr>
<td>Ethiopia-1</td>
<td>Science labs</td>
<td>Labs built, furnished, equipped. Improper use of labs &amp; equipment; teaching still traditional—no student participation in lab.</td>
</tr>
<tr>
<td>Ethiopia-3</td>
<td>Materials teacher educ. equipment</td>
<td>Center to develop &amp; evaluate curricula &amp; materials working effectively. Teacher pre- and inservice education provided at center. Prototype equipment developed at center.</td>
</tr>
<tr>
<td>Ethiopia-5</td>
<td>Science labs</td>
<td>Not all labs built. Increased enrollment in sec. schools.</td>
</tr>
<tr>
<td>Gabon-1</td>
<td>Science labs</td>
<td>Construction completed on time. Not enough equipment for all students; poor maintenance; damaged equipment delivered.</td>
</tr>
<tr>
<td>Ivory Coast-2</td>
<td>Curriculum development</td>
<td>Studies on lower secondary science curriculum dropped as no agreement on implementation.</td>
</tr>
<tr>
<td>Liberia-1</td>
<td>Pre- &amp; inservice teacher ed.</td>
<td>Equipment &amp; tools delivered, impact not known. Still poor quality entrants into college since profession not attractive; high repeater rates; high dropout rates.</td>
</tr>
<tr>
<td>Liberia-3</td>
<td>Science centers</td>
<td>No centers operational, utilities not connected. Student buses to centers deleted. No qualified teachers available to run the centers at the salary available. Lack funds to maintain equipment &amp; buildings.</td>
</tr>
<tr>
<td>Madagascar</td>
<td>Prototype equipment</td>
<td>Center operational; production of glassware &amp; chemicals exceeding plans thus need to move to larger premises.</td>
</tr>
<tr>
<td>Malawi-4</td>
<td>Preservice teacher ed.</td>
<td>Labs &amp; equipment at teacher training institute making improvements in quality of teachers.</td>
</tr>
<tr>
<td>Mali-1</td>
<td>Science labs</td>
<td>No. of labs reduced as cost overruns. Labs &amp; equipment meet planned purposes. Enrollment growing faster than expected.</td>
</tr>
<tr>
<td>Mali-1</td>
<td>Inservice teacher ed.</td>
<td>Teacher inservice successful, meeting needs. Curriculum not yet completed, considered innovative &amp; practical. Materials not reached all schools because of printing problems.</td>
</tr>
<tr>
<td>Mali-2</td>
<td>Urban science centers</td>
<td>Lab use overloaded, difficult to sustain. Teaching quality not satisfactory. Problem with resupply of consumables, maintenance.</td>
</tr>
</tbody>
</table>
TABLE C.2 (continued)

Project Outcomes by Region, Africa

<table>
<thead>
<tr>
<th>PROJECT</th>
<th>COMPONENT</th>
<th>OUTCOMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mali-2</td>
<td>Rural science centers</td>
<td>All rural schools equipped with multi-purpose labs. Pilot enviroa. science program had limited impact as not integrated, not practical.</td>
</tr>
<tr>
<td>Mali-2</td>
<td>Inservice ed.</td>
<td>Training too short to cover all topics; lack of funds to train all.</td>
</tr>
<tr>
<td>Mauritius-1</td>
<td>Science centers</td>
<td>Centers turned into jr. secondary schools by government policy.</td>
</tr>
<tr>
<td>Mauritius-3</td>
<td>Science labs</td>
<td>All facilities provided, high quality. Exam results improving; teaching quality high; courses prepare students for specialization.</td>
</tr>
<tr>
<td>Nigeria-1</td>
<td>Science labs</td>
<td>Labs not fully used because of lack of equipment, supplies, qualified teachers. Poor maintenance of equipment.</td>
</tr>
<tr>
<td>Nigeria-2</td>
<td>Labs, curric.</td>
<td>Most labs completed &amp; used. Revised practical curriculum implemented.</td>
</tr>
<tr>
<td>Senegal-2</td>
<td>Science centers</td>
<td>8 of 11 centers provided &amp; in use. Increase in science stream. Overequipped with sophisticated equipment; hard to maintain.</td>
</tr>
<tr>
<td>Senegal-2</td>
<td>Inservice ed.</td>
<td>Specialists provided teacher training, curriculum and materials development—their work not reviewed.</td>
</tr>
<tr>
<td>Senegal-3</td>
<td>Specialists</td>
<td>Specialists evaluated student achievement in practical work.</td>
</tr>
<tr>
<td>Sierra Leone-2</td>
<td>Curriculum blocks</td>
<td>No government policy guidance on use of curriculum, science blocks. Lack of qualified teachers.</td>
</tr>
<tr>
<td>Somalia-1</td>
<td>Science labs</td>
<td>Labs built &amp; equipped as planned. Poor lab maintenance, clogged sinks, broken plumbing fixtures. Too much unused sophisticated equipment, too few simple instruments.</td>
</tr>
<tr>
<td>Somalia-2</td>
<td>Science labs</td>
<td>Not all schools got labs; labs underutilized since shortage of qualified science teachers. Ventilation in labs allowed in sand.</td>
</tr>
<tr>
<td>Somalia-2</td>
<td>Science specialist</td>
<td>Specialist assigned to kit production at curriculum center underutilized. Teachers abroad on fellowships did not return.</td>
</tr>
<tr>
<td>Sudan-1</td>
<td>Science labs</td>
<td>Labs &amp; equipment at all but 2 schools; 2/3 students in science stream.</td>
</tr>
<tr>
<td>Sudan-1</td>
<td>Preservice teacher ed.</td>
<td>Still shortage of science teachers due to immigration of trained teachers to Gulf Sts. No qualitative review of teacher ed. program.</td>
</tr>
<tr>
<td>Tanzania-5</td>
<td>Science labs</td>
<td>Not all equipment delivered &amp; in use. Shortage of qualified teachers, insufficient attention to teacher needs.</td>
</tr>
</tbody>
</table>
TABLE C.2 (continued)

Project Outcomes by Region, Africa

<table>
<thead>
<tr>
<th>PROJECT</th>
<th>COMPONENT</th>
<th>OUTCOMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uganda-1</td>
<td>Science labs</td>
<td>An increase in secondary graduates with science background. Equipment badly kept; lack of expendables; useless sophisticated equipment</td>
</tr>
<tr>
<td>Uganda-3</td>
<td>Science labs</td>
<td>All equipment &amp; materials received. Consumables problem; maintenance problem. Teacher &amp; parent attitudes positive.</td>
</tr>
<tr>
<td>Zaire-1</td>
<td>Preservice teacher education</td>
<td>Teacher practice lab dropped for cost over-run--no review of teacher ed. program. Student enrollment exceeded plans--labs crowded, lack of teachers. Poor maintenance of equipment.</td>
</tr>
<tr>
<td>Zambia-1</td>
<td>Science labs equipment</td>
<td>Labs well utilized. Good functional equipment. Educational objectives received inadequate attention. Lack of qualified teachers.</td>
</tr>
</tbody>
</table>
TABLE C.3

Project Outcomes by Region, Asia
(PHREE Review of Evaluation Reports on Project Implementation)

<table>
<thead>
<tr>
<th>PROJECT</th>
<th>COMPONENT</th>
<th>OUTCOMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Korea-1</td>
<td>Preservice ed.</td>
<td>Provision of science equipment for teacher preservice not reviewed.</td>
</tr>
<tr>
<td>Malaysia-1</td>
<td>Inservice teacher ed.</td>
<td>Syllabus revised; materials &amp; textbooks produced in quantity. Inservice teacher training successful.</td>
</tr>
<tr>
<td>Malaysia-1</td>
<td>Materials</td>
<td>Educational TV used to facilitate implementation of revised curriculum; TV unit fully equipped &amp; operational.</td>
</tr>
<tr>
<td>Malaysia-3</td>
<td>Science labs</td>
<td>Facilities provided led to increase in sec. science enrollment, &amp; university. Qualitative improvement not realized; student performance still poor.</td>
</tr>
<tr>
<td>Malaysia-3</td>
<td>Sec. sci. curriculum</td>
<td>Educational TV &amp; radio are relevant to curricula but not effectively used; teachers switch on TV without explanation &amp; follow-up after.</td>
</tr>
<tr>
<td>Philippines-2</td>
<td>Instructional materials</td>
<td>Educational center to prepare textbooks, teacher guides, other materials operating properly. Low quality furniture.</td>
</tr>
<tr>
<td>Philippines-2</td>
<td>Inservice teacher ed.</td>
<td>Training in use of new materials taking place appropriately.</td>
</tr>
<tr>
<td>Philippines-3</td>
<td>Curriculum materials</td>
<td>Centers to produce materials equipped &amp; furnished. Center developed expected number of student texts &amp; teachers' guides.</td>
</tr>
<tr>
<td>Philippines-3</td>
<td>Inservice ed. training trainers</td>
<td>Center organized successful program to educate teachers and teacher trainers on use of new instructional materials.</td>
</tr>
<tr>
<td>Thailand-3</td>
<td>Pre- &amp; in-service teacher ed.</td>
<td>Resources used mainly to send teachers abroad on fellowships not local pre- &amp; inservice courses as originally planned.</td>
</tr>
<tr>
<td>Thailand-4</td>
<td>Science labs</td>
<td>Facilities fully used but overcrowded since unexpected increase in enrollment. Teacher force considered qualified. Low quality of some furniture &amp; equipment.</td>
</tr>
<tr>
<td>Thailand-6</td>
<td>Science labs</td>
<td>All labs equipped &amp; furnished. Student enrollment did not increase as planned. Some indication of student academic improvement in science noted.</td>
</tr>
<tr>
<td>PROJECT</td>
<td>COMPONENT</td>
<td>OUTCOMES</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Egypt-1</td>
<td>Science labs</td>
<td>Equipment reduced as change in curriculum deemphasized lab work.</td>
</tr>
<tr>
<td>Egypt-1</td>
<td>Inservice maintenance</td>
<td>Fellowship program to train the teacher trainers on use &amp; maintenance of equipment very successful; problem with poor English of the fellows.</td>
</tr>
<tr>
<td>Egypt-2</td>
<td>Science labs</td>
<td>All labs constructed &amp; equipped.</td>
</tr>
<tr>
<td>Egypt-2</td>
<td>Preservice teacher ed.</td>
<td>Computers, equipment received &amp; installed for preservice teacher education. Overseas fellowships for teacher trainers very high standard, most helpful to faculty of education for curricula &amp; instruction.</td>
</tr>
<tr>
<td>Egypt-3</td>
<td>Pre- &amp; in-service</td>
<td>All equipment provided &amp; installed for preservice teachers; computers allowing introduction of more modern techniques. Fellowship program for teacher trainers successful leading to improvement in teaching both theory &amp; lab to teachers. Content &amp; pedagogy upgraded in classroom, better student motivation. Maintenance problems with sophisticated equipment.</td>
</tr>
<tr>
<td>Iraq-1</td>
<td>Science blocks</td>
<td>Most labs lacked utilities &amp; consumables; inadequate storage. Tables did not have acid resistant tops. No inservice training provided on use of equipment; teachers did not recognize much of equipment.</td>
</tr>
<tr>
<td>Jordan-1</td>
<td>Preservice teacher ed.</td>
<td>Emphasis on science in preservice teacher training did not occur—limited availability of effective science in secondary schools, plus students preferred to go into medicine &amp; engineering. Poor utilization of science facilities in teacher training institutes.</td>
</tr>
<tr>
<td>Jordan-2</td>
<td>Science blocks</td>
<td>5 provided, equipped &amp; fully operational.</td>
</tr>
<tr>
<td>Morocco-1</td>
<td>Science labs</td>
<td>Lab facilities, equipment, provided but poorly maintained.</td>
</tr>
<tr>
<td>Morocco-2</td>
<td>Science blocks</td>
<td>Science blocks well-equipped and well-utilized by students; but labs overcrowded leading to deterioration of fixtures. Increase in no. of students passing the science baccalaureate.</td>
</tr>
<tr>
<td>Morocco-3</td>
<td>Science labs</td>
<td>All labs provided &amp; fully operational; increased science enrollment. Equipment &amp; furniture excellent &amp; appropriate.</td>
</tr>
<tr>
<td>Morocco-3</td>
<td>Curriculum</td>
<td>New curriculum developed by experts, implemented in project schools.</td>
</tr>
<tr>
<td>Morocco-5</td>
<td>Pre- &amp; inserv. teachers</td>
<td>Facilities provided, building capacity exceeded needs. Training successful but no effort made to upgrade science programs.</td>
</tr>
</tbody>
</table>
### TABLE C.4 (continued)

**Project Outcomes by Region, EMENA**
*(PHREE Review of Evaluation Reports on Project Implementation)*

<table>
<thead>
<tr>
<th>PROJECT</th>
<th>COMPONENT</th>
<th>OUTCOMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portug.-2</td>
<td>Science blocks</td>
<td>Impact not determined because of construction delays</td>
</tr>
<tr>
<td>Tunisia-2</td>
<td>Science labs</td>
<td>Civil work completed with speed &amp; efficiency; furniture, equipment, facilities provided with no major problem. Teaching still traditional with little practical work; equipment hardly used; no qualitative improvement.</td>
</tr>
<tr>
<td>YAR-1</td>
<td>Science labs</td>
<td>Equipment provided—impact not reviewed.</td>
</tr>
<tr>
<td>YAR-2</td>
<td>Prototype equipment</td>
<td>Center to produce prototype equipment implementing modest program of design &amp; development. Limited by staff, no. &amp; training.</td>
</tr>
<tr>
<td>Yemen</td>
<td>Science labs</td>
<td>Science lab in each school not sufficient to cover all sciences taught. Untreated wood used in construction infested with insects.</td>
</tr>
<tr>
<td>PROJECT</td>
<td>COMPONENT</td>
<td>OUTCOMES</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Barbados-i</td>
<td>Sci. labs/rooms</td>
<td>Enrollment aims met; quality of teaching has improved.</td>
</tr>
<tr>
<td>Brazil-2</td>
<td>Science centers</td>
<td>Some centers converted to primary schools. Lack of qualified teachers &amp; consumables limiting use of equipment.</td>
</tr>
<tr>
<td>Columbia-1</td>
<td>Science labs</td>
<td>Science component of project not mentioned in evaluation.</td>
</tr>
<tr>
<td>Columbia-3</td>
<td>Science centers</td>
<td>Cut back on numbers of centers due to government reforms. Limited implementation of revised curriculum. Poor construction of centers.</td>
</tr>
<tr>
<td>Costa Rica-1</td>
<td>Science labs</td>
<td>All labs suitably built, being used to implement curriculum changes.</td>
</tr>
<tr>
<td>Costa Rica-1</td>
<td>Inservice</td>
<td>Specialists running program considered very good, providing useful assistance. Courses given well-received.</td>
</tr>
<tr>
<td>Dominican Republic-1</td>
<td>Science labs</td>
<td>Problems with utilities, lack of prep. rooms. Revised curriculum not well-accepted by teachers, students, &amp; parents because of lack of communication of aims; no timely discussion with teachers, principals.</td>
</tr>
<tr>
<td>Dominican Republic-2</td>
<td>Science labs</td>
<td>Secondary education component dropped due to funds, difficulties in equipment procurement &amp; distribution.</td>
</tr>
<tr>
<td>Ecuador-1</td>
<td>Science labs</td>
<td>Incomplete construction; lack tables, utilities; poor design. More schools offering science. Quality improvements in science teaching; practicals promoting active student involvement; equipment well used.</td>
</tr>
<tr>
<td>Salvador-1</td>
<td>Science labs</td>
<td>Poor maintenance of building &amp; equipment. Non-systematic teacher training hindering use of new facilities.</td>
</tr>
<tr>
<td>El Salvador-2</td>
<td>Science labs</td>
<td>Some labs eliminated from project; labs put at disposal of army. Ed objectives not clear &amp; not fully achieved; civil unrest in country.</td>
</tr>
<tr>
<td>El Salvador-2</td>
<td>Preservice</td>
<td>Still an inadequate supply of science teachers graduating.</td>
</tr>
<tr>
<td>Guatemala-1</td>
<td>Science labs</td>
<td>Equipment provided &amp; suitable; not all labs fully utilized. Quality improvement in science teaching observed.</td>
</tr>
<tr>
<td>Guatemala-1</td>
<td>Pre- &amp; in-service</td>
<td>Poor coordination between university &amp; ministry of education preventing better use of project facilities.</td>
</tr>
<tr>
<td>Guatemala-2</td>
<td>Science centers</td>
<td>Centers functional but not all yet in operation in marginal urban areas &amp; medium-size cities. Unused sophisticated equipment.</td>
</tr>
<tr>
<td>Guyana-1</td>
<td>Science labs</td>
<td>Appropriate equipment &amp; well-designed furniture. Only partial use of labs but expected to improve as teachers shift to practical science. Effect on students not yet assessed.</td>
</tr>
<tr>
<td>Nicaragua-1</td>
<td>Science labs</td>
<td>Met most of objectives despite problems.</td>
</tr>
<tr>
<td>Paraguay-3</td>
<td>Science labs</td>
<td>All labs built &amp; equipped, problems with utilities.</td>
</tr>
<tr>
<td>Paraguay-3</td>
<td>Inservice</td>
<td>Teachers trained in use of equipment but cannot use labs because of lack of water.</td>
</tr>
<tr>
<td>Peru-1</td>
<td>Inservice</td>
<td>Not successful—problems in finding local counterparts to work with outside experts &amp; difficulty of experts in adjusting to locality.</td>
</tr>
</tbody>
</table>
**TABLE C.6**
Suggestions from the Project Completion Report  
(PHREE Review of Evaluation Reports on Program Implementation)

<table>
<thead>
<tr>
<th>PROJECT</th>
<th>SUGGESTIONS FROM PROJECT COMPLETION REPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethiopia-3</td>
<td>Need for better procurement &amp; distribution of imported instructional materials.</td>
</tr>
<tr>
<td>Kenya-2</td>
<td>Need to keep up-to-date inventories of equipment.</td>
</tr>
<tr>
<td>Mali-1</td>
<td>Science education specialists needed in the later stages of program implementation rather than the earlier.</td>
</tr>
<tr>
<td>Mali-2</td>
<td>Central ministry needs strengthening to support long-term reform effort.</td>
</tr>
<tr>
<td>Senegal-2</td>
<td>Need maintenance budget, less expensive instruments. Better use of existing centers.</td>
</tr>
<tr>
<td>Somalia-1</td>
<td>Students &amp; school staff should be instructed on how to care for equipment &amp; facilities.</td>
</tr>
<tr>
<td>Sudan-1</td>
<td>Comparison study should be conducted between project &amp; non-project schools; implementation capacity of country should be reviewed with remedies provided.</td>
</tr>
<tr>
<td>Swaziland-2</td>
<td>Incentives need to be provided to encourage better qualified teachers to rural schools.</td>
</tr>
<tr>
<td>Tanzania-5</td>
<td>Equipment needs to be inspected prior to shipment by technical experts.</td>
</tr>
<tr>
<td>Uganda-1/3</td>
<td>Any future projects should include an equipment &amp; lab maintenance service; also a system to supply and control expendables.</td>
</tr>
<tr>
<td>Malaysia-1</td>
<td>Educational TV more useful if more TV sets available, &amp; viewing time extended.</td>
</tr>
<tr>
<td>Malaysia-3</td>
<td>More attention should be given to professional aspects such as coordination &amp; leadership in use of media &amp; training for teachers &amp; other school personnel.</td>
</tr>
<tr>
<td>Thailand-6</td>
<td>Need follow-up study to determine if facilities used as planned. Need teacher inservicing to accompany large investment in labs &amp; equipment.</td>
</tr>
<tr>
<td>Egypt-1</td>
<td>Funds needed to provide language training for all fellows.</td>
</tr>
<tr>
<td>Jordan-2</td>
<td>Coordinate delivery times with construction. More staff for equipment warehouse to prevent overcrowding &amp; hence deterioration of equipment.</td>
</tr>
<tr>
<td>Morocco-1</td>
<td>More attention needs to be paid in future projects to procedures for drawing up equipment lists, &amp; installing &amp; maintaining equipment.</td>
</tr>
<tr>
<td>Morocco-2</td>
<td>Project would be strengthened by use of educators to draw up equipment lists, &amp; educational worksheets; greater participation of educators whose specialties match the project requirements.</td>
</tr>
<tr>
<td>YAR-2</td>
<td>Staff training needed in order to use centers effectively.</td>
</tr>
<tr>
<td>Barbados-1</td>
<td>Specification of complex equipment by knowledgeable educators to assure successful tender.</td>
</tr>
<tr>
<td>Brazil-2</td>
<td>Cost of consumables should be included in budget for equipment.</td>
</tr>
<tr>
<td>Dominican Republic-1</td>
<td>Storage facilities should be provided at an early stage; supervision of the implementation should continue for 6 years to measure student improvements.</td>
</tr>
<tr>
<td>El Salvador-1</td>
<td>Instructional materials should accompany lab provision; more consumeable supplies needed.</td>
</tr>
<tr>
<td>Guatemala-1</td>
<td>Better coordination between universities &amp; ministry of education to produce coherent plan to improve preservice teacher training, &amp; increase the supply of qualified teachers; clearer definition of educational objectives.</td>
</tr>
</tbody>
</table>
TABLE C.7

Togo-II: Summary Project Cost Estimate

(US$ 000)

<table>
<thead>
<tr>
<th>Categories (cost net of taxes and duties)</th>
<th>Local</th>
<th>Foreign</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil works</td>
<td>653.2</td>
<td>411.6</td>
<td>1,064.8</td>
</tr>
<tr>
<td>Furniture</td>
<td>140.2</td>
<td>82.3</td>
<td>222.5</td>
</tr>
<tr>
<td>Equipment</td>
<td>75.4</td>
<td>2,150.0</td>
<td>2,225.4</td>
</tr>
<tr>
<td>Consultant services</td>
<td>92.0</td>
<td>1,150.5</td>
<td>1,242.5</td>
</tr>
<tr>
<td>Training costs</td>
<td>2,193.2</td>
<td>473.5</td>
<td>2,666.7</td>
</tr>
<tr>
<td>Salaries of project staff</td>
<td>293.7</td>
<td>-</td>
<td>293.7</td>
</tr>
<tr>
<td>Contractual fees for teacher subs.</td>
<td>2,799.8</td>
<td>-</td>
<td>2,799.8</td>
</tr>
<tr>
<td>Other operating costs</td>
<td>539.0</td>
<td>808.6</td>
<td>1,347.6</td>
</tr>
<tr>
<td>Total base cost</td>
<td>6,785.5</td>
<td>5,076.5</td>
<td>11,863.0</td>
</tr>
<tr>
<td>Physical contingencies</td>
<td>86.9</td>
<td>264.4</td>
<td>351.3</td>
</tr>
<tr>
<td>Price contingencies</td>
<td>1,082.7</td>
<td>711.8</td>
<td>1,794.5</td>
</tr>
<tr>
<td>Total project cost</td>
<td>7,956.1</td>
<td>6,032.7</td>
<td>14,008.8</td>
</tr>
</tbody>
</table>

Rounded                                                                 |

<table>
<thead>
<tr>
<th>Local</th>
<th>Foreign</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>7,950</td>
<td>6,050</td>
<td>14,000</td>
</tr>
</tbody>
</table>

Financing Plan: Organization

<table>
<thead>
<tr>
<th>IDA</th>
<th>Government</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>6,350</td>
<td>1,600</td>
<td>7,950</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Financial Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996-1997</td>
</tr>
<tr>
<td>1997-2000</td>
</tr>
<tr>
<td>2000-2003</td>
</tr>
<tr>
<td>2003-2006</td>
</tr>
<tr>
<td>Table C.8</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td><strong>Ministry of Education (MOE)</strong></td>
</tr>
<tr>
<td>(1) Instructional equipment, books and materials</td>
</tr>
<tr>
<td>(2) Consultant services, fellowships, studies, &amp; repatriation costs</td>
</tr>
<tr>
<td>(3) Initial deposit in the MOE special account</td>
</tr>
<tr>
<td><strong>Korea Science and Engineering Foundation (KOSEF)</strong></td>
</tr>
<tr>
<td>(4) Consultant services and fellowships</td>
</tr>
<tr>
<td>(5) Research grants</td>
</tr>
<tr>
<td>(6) Initial deposit in the KOSEF special account</td>
</tr>
<tr>
<td><strong>Korea Advanced Institute of Science and Technology (KAIST)</strong></td>
</tr>
<tr>
<td>(7) Instructional equipment, books and materials</td>
</tr>
<tr>
<td>(8) Consultant services, fellowships and repatriation costs</td>
</tr>
<tr>
<td>(9) Initial deposit in the KAIST special account</td>
</tr>
<tr>
<td><strong>Other</strong></td>
</tr>
<tr>
<td>(10) Front-end fee</td>
</tr>
<tr>
<td>(11) Unallocated</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
<tr>
<td><strong>Amount of loan cancelled</strong></td>
</tr>
<tr>
<td>Description</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Improving the quality of education (curriculum, textbook and materials development, and evaluation)</td>
</tr>
<tr>
<td>Improving the quality of teacher education (upgrading the preservice and inservice teacher education)</td>
</tr>
<tr>
<td>Improving management skills and practices (management assessment and development and administrator training)</td>
</tr>
<tr>
<td>Base cost</td>
</tr>
<tr>
<td>Physical contingencies</td>
</tr>
<tr>
<td>Price contingencies</td>
</tr>
<tr>
<td>Total project costs</td>
</tr>
<tr>
<td>Financing Plan</td>
</tr>
<tr>
<td>IBRD</td>
</tr>
<tr>
<td>Government</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>
APPENDIX D

FEMALES IN SCIENCE

This report has mentioned the topic of female participation in science only briefly. This does not imply that the issue is insignificant, quite the reverse. This topic is so important and, in many countries, so interwoven with sociocultural constraints placed upon female education in any subject, as to require a separate study. Since the World Bank is already exploring concerns related to the higher education of women in such a study (DePietro, 1991), this report will only very briefly point out some issues.

In most countries, a smaller percentage of girls are found in the science stream than boys; this percentage gets smaller and smaller as the girls grow into young women. This is less of a problem in biology classes, and more of a concern in physics (and, later, engineering) programs. Young women who do not take science subjects in school do not study science at university. This situation represents an appalling waste of intellectual capital, even apart from the equity issues raised.

Where "science for all" is the goal, as discussed in Chapter 1, there are additional reasons to be concerned that young women have an opportunity to learn, and enjoy learning, science. In many developing countries, women are almost totally responsible for subsistence farming. In all countries, women are the prime care-givers—raising and rearing children, tending to the sick members of the family, selecting and cooking meals, fetching water, washing clothes, etc. The very quality of life issues that are included in the second-wave science courses are directly related to the everyday duties of many women. The use, and understanding, of science and appropriate technology by women in development would do much to improve the quality of life for all in the community (Sigot, 1990).

While there has been a great deal of discussion on why female participation in science is so low, there are basically two explanations attempted: (i) that females are either intellectually or emotionally incapable of being "great" scientists (i.e., the nature of women precludes their participation); or (ii) that girls are conditioned by society to view science as, somehow, an unfeminine pursuit, and therefore eliminate themselves from the science stream (i.e., the nurture of females, from the earliest of ages, precludes their participation). The first supposition is nonsense. The body of the evidence supports the latter explanation.

Table D.1 is a sample of some studies on girls in science in developing countries. Although the points made refer to specific countries, they are general enough to apply to most.

As discussed in Chapter 1, there is some reason to believe that the STS-approach to teaching science will help counteract many of the negative images that girls have themselves expressed about science. The larger issue of societal expectations for females is a much less tractable problem to solve.
TABLE D.1

Girls in Science in Developing Countries

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>SUBJECT</th>
<th>COMMENTS</th>
<th>REFERENCE</th>
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<tbody>
<tr>
<td>Nigeria</td>
<td>Science</td>
<td>Girls' attitudes more positive in single sex schools, urban schools, schools with well-equipped and used laboratories</td>
<td>Ato, 1990</td>
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<td>India</td>
<td>Electricity</td>
<td>Girl dropouts from rural areas enroll in electrical course run by university, taught to repair defective appliances. Girls did so well university tempted to offer courses in wiring and electronics. Girls commented that school science &quot;dry and lacking first hand practical experience.&quot;</td>
<td>Papa, 1990</td>
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<td>Botswana</td>
<td>Science, math</td>
<td>Science and math teachers in secondary schools tend to be male; art, music, Setswana, and English teachers tend to be female, reinforces stereotype that girls don't do science; females in textbooks shown as passive and weak; career survey showed girls did not pick science as a suitable occupation—strong evidence of career stereotyping</td>
<td>Duncan, 1989</td>
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<td>Jordan</td>
<td>Secondary science</td>
<td>Enrollment rates of girls in first year of sec. sci. improved from 501 in 1967 (33% female, enrollment) to 5305 (40%)in 1987</td>
<td>Tel, 1990</td>
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<tr>
<td>Sierra Leone</td>
<td>Science, math, tech</td>
<td>Boys received greater attention and encouragement in science, math, &amp; tech than girls; parents and teachers had higher expectations for boys</td>
<td>Amara, 1985</td>
</tr>
<tr>
<td>Kenya</td>
<td>Science, math, tech</td>
<td>Boys received greater attention and encouragement in science, math, &amp; tech than girls; parents and teachers had higher expectations for boys</td>
<td>Eshiwnani, 1983</td>
</tr>
<tr>
<td>Zambia</td>
<td>Science, math, tech</td>
<td>Boys received greater attention and encouragement in science, math, &amp; tech than girls; parents and teachers had higher expectations for boys</td>
<td>Shifferaw, 1982</td>
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<td>Ghana</td>
<td>Science</td>
<td>12% elect to study chemistry, physics, biology; 5% girls in math; reasons are: &quot;science not relevant to everyday life,&quot; lack of role models; remedial strategies (i) 2-week science clinic for 110 secondary school girls to promote science careers, present role models, identify strategies to encourage more girls into science, (ii) second clinic for 75 girls, (iii) brochure on Women in Science in Ghana</td>
<td>Andam, 1990</td>
</tr>
<tr>
<td>Thailand</td>
<td>Science</td>
<td>About equal participation of girls in secondary science</td>
<td>Soydhurum, 1990a</td>
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<td>Chile</td>
<td>Technology</td>
<td>Girls' technical school &amp; boys' mechanical school combined to give more course offerings — boys took more advantage of variety, girls' response much less</td>
<td>Fillain, 1975</td>
</tr>
</tbody>
</table>
Selected References


