UNESCO Resource Kit

Science & Technology Education

Philosophy of Project 2000+

Scientific & Technological Literacy for all
In a world increasingly shaped by science and technology, Scientific and Technological Literacy (STL) is a universal requirement if people are not to be alienated in some degree from the society in which they live. It is vital to improve scientific and technological literacy.

We need, through educational means of all kinds, formal and non-formal, to bring about a much more thorough infusion of scientific and technological culture into society. Only in this way shall we succeed in creating the continuum, the virtuous circle encompassing the establishment of a broad educational base in science and technology, enhanced capacity to cope with change and to pursue development goals, scientifically informed decision making, and finally - completing the circle - expanding investment in human development.

_Federico Mayor, Director-General, UNESCO._

Project 2000+ Steering Committee

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2 UNESCO
Scientific and Technological Literacy (STL)
what STL means for Teachers and their Students
with particular reference to pre-service, in-service
and distance science teacher education

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Written by Patrick Whittle & Ved Goel
Editor - Caroline McGrath

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The Origins and Purpose of Project 2000+

Project 2000+ is a collaborative partnership between eleven major international agencies and inter-governmental organisations with particular concerns and responsibilities for research and development in the field of science and technology education. At an International Forum in 1993, 400 participants from 80 countries met in Paris to establish a global agenda supporting individuals, institutions, organisations and governments working towards the reform and revitalisation of science and technology education at all levels. The Project 2000+ Declaration found its driving force in the previous World Declaration of Education for All and the Rio Declaration on Environment and Development. It pointed out that sustainable development is dependent upon a scientific and technologically literate population and called on governments, industry, public and private sector interests to review educational provision. Priority should be given to providing equal access for all boys, girls, men and women to science and technology. It called for continuing provision for teacher education in this field and for task forces to be set up to foster scientific and technological literacy for all by developing educational activities designed to set science and its applications in a wider social and cultural environment.

The 1993 Declaration urged agencies, NGOs, INGOs and governments to work together to advance the capability of countries for designing, planning and implementing programmes to enhance scientific and technological literacy for all. It recommended that UNESCO made provision during this decade for an international programme of co-operation in the field of science and technology education. This programme has focussed on strengthening regional and sub-regional networks for exchange of ideas, information, human and material resources. Its goal is to foster scientific and technological literacy for all by promoting, worldwide:-

- understanding of the nature of, and need for, scientific and technological literacy in relation to local culture and values and national social and economic needs and aspirations;
- identification of issues of special importance for personal, local and national development;
- establishment of suitable teaching and learning environments and structures;
- formulation of guidelines for on-going professional development and leadership;
- development of effective communication, assessment and evaluation strategies;
- support for non-formal, informal and life-long learning strategies.

Finally it recommended that by year 2001 there should be in place appropriate structures and activities to foster scientific and technological literacy for all, in all countries.

During this decade some progress has been made towards these goals in many regions and individual countries, where conferences, workshops and seminars have been held to promote scientific and technological literacy for all. Much of this activity...
has involved practising teachers upon whom any advances in education depend. With international collaboration and support, several national science teachers' associations have hosted workshops to develop guidelines, and trial materials for promoting scientific and technological literacy (STL).

A body of literacy now exists in this field, and the resource kit of which this booklet is part is tangible evidence of the progress of Project 2000+.

However, in order to meet the target, appropriate structures and activities to foster STL for all still have to be developed and refined in many countries. It is hoped that this resource kit will be the catalyst through which that goal will be achieved. Not all teachers will find it possible to select a ready-made module from the Resource Manual of this kit, or the supplementary teaching materials written in Argentina, Estonia, Nepal or Nigeria. The purpose of Project 2000+ is to share these ideas and to stimulate teachers in a new country or locality to develop and write their own local STL materials suited to the needs of their own students. The written modules and the videotape in this kit are provided to start you thinking about how your own primary or secondary science lessons, or even tertiary science education lectures, could be modified to promote more effective scientific and technological literacy for all. Only you know all the local constraints and parameters, expectations and requirements, and so you and your colleagues are the key personnel to promote the Project 2000+ goals in your own locality.

Further sections of this booklet suggest ways in which the resource kit may be used either for institutional programmes of initial teacher training, or for in-service teacher upgrading work. Alternatively it may be used by individuals, for distance teacher education, or informal meetings arranged by a national or local science teacher association. The focus, however, is in all cases the enhancement of scientific and technological literacy. The next section examines in some detail definitions of STL and some of the criteria for STL activities and materials.
The Meaning of Scientific and Technological Literacy

What is STL?

Scientific and technological literacy, in its broadest sense, means much more than simply being able to read, understand and write about science and technology, however important these are. STL also includes the ability to apply scientific and technological concepts and process skills to the life, work and culture of one's own society. It therefore includes attitudes and values enabling one to distinguish between worthwhile or inappropriate uses of science or technology. Hence scientific and technological literacy implies:

- the development of scientific and technological attitudes, approaches and skills which are necessary to cope with a rapidly changing environment and which are useful for problem-solving and decision-making in daily life;

- an appreciation of the nature of science and technology, and development of positive attitudes and values relating basic science and technology to other areas of human activity;

- exposure to effective teaching strategies and relevant examples of science and technology (at primary, secondary, tertiary or adult education) either within a formal programme, or through non-formal or distance educational methods);

- familiarisation with the processes of accessing and communicating science and technology information and a willingness to use it to meet personal, local or global requirements.

It follows from the above definition that a person becomes scientifically and technologically literate by some involvement with applications of science or technology which interest them, or are intimately related to their everyday life, or which they perceive as being significant or important to them beyond the requirement of examinations. Attitudes and confidence are usually most effectively developed by significant first hand or contrived experiences.
Full-time initial teacher education programmes may be "concurrent" or "end-on" with other academic studies. In addition to subject studies of a specialist nature, most programmes of professional training for teachers in colleges or universities traditionally contained some elements of educational theory, some teaching methodology and varying amounts of exposure to classroom experience. They should be encouraged to try out some STL activities.

In recent years, practical classroom professional studies have tended to take precedence over the more abstract components of education. Theoretical educational material may be found embedded into discrete modules of curriculum and teaching studies. Student teachers are more likely to be asked to compare different methods of teaching a specific topic than to write an account of a pedagogical theory. This is especially true of part-time, in-service or school-based distance teacher education programmes, where practical constraints of time and resources require a sharp focus on classroom realities and the local environment - very suitable for STL.

Effectiveness of science teacher education is indicated when teachers show:

- good understanding of the required subject matter, professional knowledge and skills;
- proficiency in choosing suitable teaching-learning strategies and available resources;
- an emphasis on developing students' comprehension and problem-solving skills;
- enthusiasm in promoting positive attitudes to science and technology in society.

This resource kit can help promote the above goals of science teacher education, because:

- the manual contains a range of valuable 'science content' background information;
- both manual and videotape illustrate a wide range of teaching strategies;
- both manual and videotape emphasise student-centred group problem solving activities;
- both manual and videotape encourage teachers to pass on positive attitudes to students.

Nevertheless since most curricula and examinations have a bias towards factual recall, teacher education courses must focus on the content and cognitive objectives of the curriculum. The kit should be treated as enrichment material which encourages teachers to be innovative, so individual units could be included in existing courses. However, this does not preclude the possibility of introducing a new course on Teaching for Scientific and Technological Literacy drawing on theory and research to examine the ways in which STL can best be achieved.
The Project 2000+ Resource Kit contains this 16 page background booklet about STL, a 250 page resource manual for teachers containing 26 exemplar STL modules and a half-hour videotape showing traditional and innovative styles of science teaching.

Science & Technology Education - The Philosophy of Project 2000+. This booklet is written for all users of the resource kit, and especially for science teacher training for primary, middle and secondary schools. Although addressed chiefly to teacher educators, it will also be useful for curriculum developers, administrators and planners when selecting, trialling, adapting or writing innovative teaching material for their own purposes. Section 2 “What is STL?” is particularly suitable for photocopying as an introduction to modules from the resource manual, when these are being evaluated or tried out.

Science and Technology Education - Resources for the Twenty-First Century. This 250 page resource manual contains 26 exemplar STL modules for a range of interactive discussions and activities about sociological issues relating to the science and technology of transport, water, wood, biodiversity, pollution, energy resources, nutrition and numbers. These modules are summarised in Table 1 (overleaf) and outlined more fully in the front of the manual. Teachers having access to the whole manual may select and read one or more modules and select one appropriate for use by their own students - in terms of relevance, level of difficulty, availability of resources. This may be possible for school-based or distance teacher education. Institutional users of the manual may prefer to select 3 or 4 modules, photocopy them and distribute them to groups of teachers (or student teachers). Have the necessary resources ready to let each group try out one module and evaluate it. They should be encouraged to write down comments, criticisms, or suggested modifications, and report back in full plenary session.

Does the module require local adaptation?
Some topics may require more explanation.

Will any activity be modified?
Select the most interesting, motivating, interactive activities.

What materials are required?
There may be local alternative resources, data, or illustrations.

How will it be introduced?
May need background information, a local story or pictures.

Which pages should be copied for students?
Be selective, and use the board.

How will the module be followed up?
How can findings be passed on to the community.

How will assessment/evaluation be done?
Group reports or individual inputs can be tried.
Table 1

<table>
<thead>
<tr>
<th>Name of Unit</th>
<th>Major Student Activities</th>
<th>Context</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Cars and energy</td>
<td>Groups analyse and interpret car data</td>
<td>Transport</td>
<td>middle/secondary</td>
</tr>
<tr>
<td>2 Getting to school</td>
<td>Examine traffic solutions and relate to local situations</td>
<td>primary/middle</td>
<td></td>
</tr>
<tr>
<td>3 Fuels for the future</td>
<td>Comparative fuel calorimetry experiments</td>
<td>secondary</td>
<td></td>
</tr>
<tr>
<td>4 Problems with fossil fuels</td>
<td>Data interpretation for ethanol/biodiesel debate</td>
<td>secondary/higher</td>
<td></td>
</tr>
<tr>
<td>5 Osmosis</td>
<td>Role-play about a community and its power station</td>
<td>primary/middle</td>
<td></td>
</tr>
<tr>
<td>6 The water cycle</td>
<td>Evaporation, transpiration; design solar still</td>
<td>primary/middle</td>
<td></td>
</tr>
<tr>
<td>7 Sources of fresh water</td>
<td>Data interpretation; water treatment and tests</td>
<td>primary/middle</td>
<td></td>
</tr>
<tr>
<td>8 Managing water resources</td>
<td>Data analysis and role-play about a reservoir</td>
<td>primary/middle</td>
<td></td>
</tr>
<tr>
<td>9 Forests for the future</td>
<td>Tree survey, estimation and data analysis</td>
<td>primary/middle</td>
<td></td>
</tr>
<tr>
<td>10 Tropical rain forests</td>
<td>Groups interpret data, conduct CO₂ tests, debate issue</td>
<td>secondary</td>
<td></td>
</tr>
<tr>
<td>11 Wood as a fuel</td>
<td>Groups conduct wood stove tests and analyse data</td>
<td>secondary</td>
<td></td>
</tr>
<tr>
<td>12 Wood as a structural material</td>
<td>Testing properties of wood and interpret data</td>
<td>secondary</td>
<td></td>
</tr>
<tr>
<td>13 Materials made from wood</td>
<td>Groups make test paper, plywood, chipwood</td>
<td>secondary</td>
<td></td>
</tr>
<tr>
<td>14 Understanding biodiversity</td>
<td>Food chains, creating a garden, making a mural</td>
<td>primary/middle</td>
<td></td>
</tr>
<tr>
<td>15 Cloning sheep</td>
<td>Sequence cloning process</td>
<td>secondary</td>
<td></td>
</tr>
<tr>
<td>16 Investigating pollution</td>
<td>Survey atmospheric and water pollution</td>
<td>secondary</td>
<td></td>
</tr>
<tr>
<td>17 Sorting out waste</td>
<td>Classify/sort/survey: investigate decay</td>
<td>secondary</td>
<td></td>
</tr>
<tr>
<td>18 Noise pollution</td>
<td>Noise survey, discussion and community action</td>
<td>secondary</td>
<td></td>
</tr>
<tr>
<td>19 Combined heat and power</td>
<td>Discuss and analyse data on CHP plant</td>
<td>secondary</td>
<td></td>
</tr>
<tr>
<td>20 Solar heating</td>
<td>Design and evaluate solar heating systems</td>
<td>middle secondary</td>
<td></td>
</tr>
<tr>
<td>21 Photovoltaics</td>
<td>Analyse and interpret solar and photovoltaic data</td>
<td>secondary</td>
<td></td>
</tr>
<tr>
<td>22 Wind power</td>
<td>Local survey and data analysis for a wind turbine</td>
<td>secondary</td>
<td></td>
</tr>
<tr>
<td>23 Alcohol in your body</td>
<td>Analyse alcohol data; promote community awareness</td>
<td>secondary</td>
<td></td>
</tr>
<tr>
<td>24 Testing the quality of food</td>
<td>Conduct food tests; dramatise community awareness</td>
<td>secondary</td>
<td></td>
</tr>
<tr>
<td>25 Understanding eclipses</td>
<td>Make models; relate evidence to historical accounts</td>
<td>secondary</td>
<td></td>
</tr>
<tr>
<td>26 Working with numbers</td>
<td>Compare orders of magnitude, estimates, scales</td>
<td>secondary</td>
<td></td>
</tr>
</tbody>
</table>

Topics and issues for you to suggest for your own local modules

<table>
<thead>
<tr>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>primary</td>
</tr>
<tr>
<td>middle</td>
</tr>
<tr>
<td>secondary</td>
</tr>
<tr>
<td>higher</td>
</tr>
</tbody>
</table>
"Styles of Science Teaching and Learning" - to promote scientific & technological literacy

This half-hour videotape illustrates some traditional and innovative styles of science teaching by primary and secondary school teachers in South America, Central Africa and Western Europe. It also shows science teachers developing and testing new materials in developing countries and is intended to stimulate thinking about improving student learning in relation to:

- the aims of teaching science for future citizens of the third millennium;
- everyday applications of science in the environment which are of benefit to society;
- various traditional and innovative styles of teaching and learning science;
- use of locally available resources, both made and natural, for science teaching;
- promotion of scientific and technological literacy among primary and secondary students and the public understanding of science and technology in society as a whole.

It shows:

- traditional teacher-centred large class teaching;
- interactive demonstrations;
- individual practical observation;
- experimental work in groups;
- games and role-play;
- problem-solving simulation activities;

- group discussions;
- marine and field visits;
- science competitions;
- inexpensive materials for experiments;
- investigations.

Some views about project work and different demands on teachers and students are mentioned. Examples of seminars, workshops and excursions (organised by ministries, universities or science teacher associations) are shown developing materials to improve teaching and learning. Some exemplary and reference materials of value in developing suitable teaching approaches for promoting effective STL are shown (published by ASE, ICASE, ICSU, NSTA, UNESCO).

The tape may be paused for teachers to discuss some questions posed by the commentary:

- what are the needs of students as they leave school to enter modern society?
- how can lessons develop students’ positive attitudes to the natural environment?
- what questions would you ask students on a visit to a solid waste disposal tip?
- how would you get your students to discuss the good and bad effects of technology?
- what is the value of students sharing and discussing experiences during field trips?
- how can scientific knowledge improve the quality of life of a community?
- are there any alternative ways of teaching the lessons which are shown?
- what are the implications for the teacher when using student centred activities?

It is recommended that after watching the video, teachers be provided with an opportunity to discuss some examples of STL modules which they can criticise, adapt, try out or re-write for their own use.
Formative Assessment of Progress in STL

In many countries, end of year and school-leaving examinations form the major part of school science assessment, for purposes of student selection. However, continuous assessment during the year is also profitable for feedback to the teacher and for monitoring of individual progress. Formative assessment of each student's progress is not easy, however, particularly in large classes. Whilst teachers should regularly check their student assignments and written work, it is also helpful to obtain regular feedback (either formal or informal) about each student.

During STL group activities, feedback can be obtained by observing each group discussion in turn, and observing the contributions of each member of the group. When groups report back findings to the rest of the class, further notes are made about individual contributions. At the end of each project, students each write a summary of what they have done. This can be assessed, and combined with the previous assessment notes. The following pattern for identifying STL assessment procedures can be recommended:

<table>
<thead>
<tr>
<th>Objective</th>
<th>Activities to achieve this</th>
<th>Assessment procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge about...</td>
<td>Inquiry, library search, reading</td>
<td>Short answer test about...</td>
</tr>
<tr>
<td>Investigate factors...</td>
<td>Follow instructions, devise experiments</td>
<td>Report investigation of...</td>
</tr>
<tr>
<td>Awareness of...</td>
<td>Group discussion, debate, role-play</td>
<td>Comment on...</td>
</tr>
<tr>
<td>Communicate about...</td>
<td>Design handout, poster, drama</td>
<td>Effectiveness of output...</td>
</tr>
</tbody>
</table>

When used for in-service teacher education, exemplar STL materials can be incorporated into day seminars or short residential courses in the same way as they are used in a full-time teacher education programme. However, time constraints will require that the modules should be used very selectively for this purpose. The advantage of this opportunity, however, is scope for participants to try out and evaluate the materials in their own school, whereas full-time students on teaching practice do not normally have freedom for such initiatives.

Distance-learning programmes provide even better opportunities for micro-studies of the use of STL materials. The ideal situation would be to incorporate one selected module into the programme, provide participants with detailed guidance for its evaluation, and ask them to write an account of the project in their school.
Developing and Evaluating Local STL Materials

Local STL materials have been written by small groups of science teachers in several countries. Usually the first step is to discuss the meaning and value of scientific and technological literacy before examining in detail, and criticising an example or examples of STL modules or scripts written elsewhere. This is best done in a group of between 3 and 6 teachers, including some with different subject specialisms or interests.

The group next holds a brainstorming session about their own preferences for an STL topic relating science and technology to society in their locality. Having agreed on a topic, they should discuss and draft their new unit of work on the basis of the following components:

- aims of the activity;
- background information required (references may be needed);
- detailed, challenging activities which will be suggested for the students;
- concepts involved (including any specialised vocabulary);
- the materials required for guidance and experimental work;
- possible outcomes and assessment procedures to be adopted.

The initial draft materials will usually require editing and typing by one member of the group.

Illustrative material, diagrams and tables of data may need to be added to the script. The final draft module should include some or all of the following components:

**Preamble**
- introduction;
- educational aims;
- scientific concepts involved;
- suggested teaching and learning activities;
- recommended teaching/learning materials.

**Student's guide**
- background information;
- the task;
- possible follow-up work.

**Teacher's guide**
- preparations necessary before the activities;
- teaching strategies;
- suggested student activities;
- background information;
- assessment guidelines.

It is unlikely that the first draft module will be perfect, and usually some revision is required in the light of evaluative feedback from trying it out with a group of students. Some guidelines for evaluation are provided overleaf.
Evaluating the effectiveness of an STL module requires asking questions after trying a module out in school (the questions being answered by teachers themselves and by students):

- How well did the module fit the curriculum?
- Which parts of the module were most useful?
- Which of the aims were achieved?
- Which key concepts did this module illuminate?
- What extra guidance was required by the students?
- Did this module relate to local community needs?
- Was it enjoyable/satisfying for the teacher to use, and use again?
- Did the students find it motivating, interesting, demanding, boring...?
- Which parts did the students find most difficult?
- Did it help the students relate science and technology to their society?
- Did students show any unexpected initiatives?
- Were students willing to make their findings known in the community?

The information from these evaluative findings can be analysed and used to make valuable improvements to any module before its further use.

Few countries can boast significant research reports about empirical studies of the relation between science teaching or learning, local social or cultural norms, and national expectations. There is considerable scope for more research on aspects of scientific and technological literacy with regard to classroom teaching strategies and the quality of student learning, as well as long term studies of community benefits from students who have experience of STL activities. Comparison of an analysis of regular science teaching and STL approaches in terms of their cognitive, psychomotor and affective components could provide valuable educational insights. There are some indications that girls may be more responsive than boys to some STL activities, and therefore this could be another area for profitable research on gender issues in relation to science, technology and society.
Bibliography


Some Useful Addresses

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Science & Technology Education

- Cars and energy
- Getting to school
- Fuels for the future
- Problems with fossil fuels
- Oremulsion
- The water cycle
- Sources of fresh water
- Managing water resources
- Forests for the future
- Tropical rain forests
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- Understanding eclipses of the Sun
- Working with numbers