ICASE2003

Increasing the Relevance of Science and Technology Education for All for the 21st Century

THE WAY FORWARD: Science Education for the 21st Century

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This is a set of recommendations is tailored to each of 10 sets of perceived stakeholders so as to move science education forward for the 21st century. In particular the recommendations are drawn up separately for each set of stakeholders based on :

1.   Reviewing the STE provision in schools

2.   Goals for STE in the 21st century.

3.   STE as a core provision within the school curriculum.

4.   STE based on standards.

5.   Giving due attention to teaching targets and approaches

6.   Relate specialisation as extension of STE goals and provisions.

7.   Role of STE on student attitudes

8.   Encouraging STE research, dissemination and supporting implementation.

9.   Valid and reliable assessment of student assessment in STE.

10.   Greater provision for the professional development of STE teachers.

11.   Ongoing professional development for STE pre- and in-service teacher educators.

12.   Official support for professional STE teacher associations.

Preface

As we enter the 21st Century, ICASE proposes there is a need for a review of the quality and status of the Science and Technology Education (STE) provision within a country.

The relevance of the STE provision is suspect in many curricula around the world. STE does little to increase the ***popularisation of science and technology in schools (EU report, 2004), or raise public awareness of science and technology among the future generation (concerns raised in the World Conference on Science, 1999).***

The relevance of science and technology education (STE) is a concern in at least three important areas:
1.   meeting the perceived educational needs and the interests of students,
2.   giving a balanced vision of the importance and socio-scientific functioning of industry. Also, being of relevance for the preparation and awareness of student careers, and
3.   reflecting the needs for a science and technology education towards societal development and socio-scientific decision-making within the society.

STE has its roots in the educational curriculum provision, often based on the separate school disciplines of science and technology (or in sub-divisions of these – biology, chemistry, geology/earth science, physics, food technology, materials technology, engineering, etc). But it is very important that we not forget that STE is **education**, and hence its goals and emphases need to be driven by **educational needs**, relevant to the students and the society in which the students are being educated. ICASE feels it is necessary to review the part played by STE and to reflect on its role, bearing in mind the strong, but necessary suitable, past influences of subject-based conceptual learning from projects of the 1960s and 1970s.

Those with an interest in STE (Governments; professional bodies, academies and associations; STE educators in Ministries of Education, Universities, STE Centres, Institutions and Schools; and "the media") should recognise the concern indicated (and hence the need for action) and agree on a framework, within a country, a region, or a locality that can be developed for greater STE relevance. The setting up of a `**national team**` (under whatever name considered appropriate and composed of a wide range of expertise, representative of those most concerned) is seen by ICASE as an important step.

The following is **a framework,** put forward for the attention of the 'national team', or whoever has interest in the challenge of increasing the relevance of STE. This framework emanates from an international conference, convened by ICASE, in April 2003 and is supported by the delegates present. It recognises all points put forward in the declaration from the ***Project 2000+ forum (UNESCO, 1993)*** and develops these further. The Project 2000+ declaration concluded by recommending that by 2001 there should be in place *"appropriate structures and activities to foster scientific and technological literacy for all in all countries'*. It will be appropriate to determine to what extent these structures are in place and working.

In addition, the framework builds on the recommendations of the ***Science Agenda - framework for Action, arising from the World Conference on Science in Budapest, Hungary in 1999,***

which urges Governments to endorse the recommended action on Science Education stated in paragraphs 41 to 49 of the report.

The Way Forward

A Framework for STE for the 21st Century

- Based on a vision that science and technology education is important for citizenship and in raising the profile of science and technology with the general public,

- Noting the vision is to enable parents and students to recognise that science and technology education is relevant for all, whatever their future careers or aspirations,

- And recognising that:
    there is a wide variation in local and regional needs and experiences,
    there is variation in the perceptions, indigenous science and technologies and interpretations of terminologies,
    the needs of students, the society and (as a specific sub-area with the society), industry, differ from locality, region or country,

the following **key recommendations** are put forward as a pathway for Science and Technology Education for the 21st century:

1.	The goals of STE should be solely ***derived from, and relate to***, the goals of Education.
2.	Achievement of the goals of STE should be measured in terms of the degree to which students acquire scientific and technological literacy (STL) to the standards determined by the society.
3.	STE should be a core provision within the school curriculum at all levels and be expected to provide a basis for acquiring skills for lifelong learning.
4.	Standards should be set for the STE provision, related to multi-dimensional STL, and student assessment should be criteria referenced on the basis on these standards.
5.	STE needs to give due attention to the STL approach in terms of relevance to the student, to industry and to the expectations of society and be based on constructivist principles.
6.	Greater efforts should be made to encourage research in STE, disseminating its results and supporting the implementation of recommendations.
7.	The validity and reliability of student assessment in STE should be increased and made more relevant to the achievement standards set for multi-dimensional STL.
8.	Greater provision should be made for the professional development of STE teachers to promote relevance in the teaching provision for multi-dimensional STL.

9.	Provision should also be made for the ongoing professional development of STE teacher educators (those leading pre-, or in-service STE) for greater STL relevance.
10.	Official support (especially in terms of recognition) should be forthcoming for professional STE teacher associations.

The recommendations are made to various bodies seen as interested in STE. The recommendations are specifically addressed to 'national teams', who are asked to reflect on the recommendations and to development them further for the specific situation in their country. And then, having their own specific recommendations, the goal is to disseminate these to the various, relevant bodies for consideration and enactment.

- **<u>No recommendation is included on content.</u>** This is deliberate. It is proposed that content must be established at local or regional levels to thus ensure context relevance to the community and to all age levels within that community. STL goals tend to suggest there is *no specific content* driving STE for the 21st Century. It is noted that some aspects of current issues providing relevance are likely to be outside any specified curriculum content.

- An ICSU conference held in India, 1985, suggested the following areas were important for STE and human needs: h*ealth, food, energy, environment, technology and industry, land/water/mineral resources, information technology and ethics/social issues.* These need careful consideration in developing the context for STE

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Explanation of Terms

STE = *science and technology education*, encompassing
science education (or its sub-components e.g. biology, chemistry, physics education);
technology education (under whatever name or sub-division); or
science and technology education as a combined programme.

STL = *scientific and technological literacy* (taken as the target, at a multi-dimensional level, for any, or all, STE programmes).

Multi-dimensional = acquiring skills and values at an intellectual, personal and social level, appropriate for the science and technology education provision at the standard indicated within the country.

This target
❖ can be expressed at many levels, depending on the width, multitude and cognition level of the specific aims to be achieved, all within the framework of the goals of education.
❖ is expected to encompass aims in all the goal areas expressed for education at that level (e.g. cognitive, process skills, communication, personal development, social skills).
❖ is for any science and technology education programme. This is because scientific literacy and technological literacy are not distinguished for one another.

NOTE: Literacy in this context relates to all goals of education. It does not simply equate to reading and writing. As such it is recognized that the term literacy does not translate well into other languages.

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NOTE also: In English, there is no difference between:

science education	and	*scientific education*
science and technology literacy	and	*scientific and technological literacy*

but there is a big difference between

science and *science education* (*or the teaching of science*)		
technology education	and	*technical education*
(related to all goals of education)		(limited mainly to the process skills component of education)
	(i.e. technological ≠ technical)	

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Document 2   **Elaboration of the Recommendations,
                       geared to various stakeholders**

The following elaborates the 12 key recommendations so as to make them more specific to various stakeholders.

The detailed statements recommend courses of action to be taken in order that all members of the "national team " can play their role in raising the popularity of STE, especially at the junior secondary level where dissatisfaction with school science subjects seems to be developed.

The following recommendations are addressed to:

- K.   Government policy makers
- L.   Curriculum developers
- M.   Teachers of STE
- N.   Teacher Educators
- O.   External Examination Authorities
- P.   UNESCO and International NGOs (ICASE)
- Q.   National Science and Technology, Professional Teacher Associations
- R.   Industrialists
- S.   Scientists or Science Academies
- T.   Science Centres or Science Museums

These recommendations build on those emanating from the International Conference on STE held in Goa, India in 2001. They stress the importance of reflecting on educational needs of students and of the society. This stress is especially related to increasing the relevance of the STE provision in schools

These recommendation also relate to the need to develop responsible citizens capable of appreciating the need for the promotion of ethical values, human rights, a culture of peace, equity for all including minorities and a vision of sustainable development and globalization.

A.   Recommendations to Government Policy Makers

Policy Makers should make STE more <u>relevant</u> to the perceived needs and interests of students, reflecting a balanced vision of the importance and socio-scientific functioning of industry, plus relevance for preparation for, and awareness of, student careers, and meeting the needs of society and the culture, by:

1.   **reviewing their STE policy, at the school level, for the 21st century**. In particular the objectives for STE programmes should be checked for their relevance against the stipulated goals of education. Also to be checked is that appropriate emphasis is given to conceptual development, skills development, personal development (including communication and cooperative learning) and moral and ethical considerations.

    This policy reflects the society need for the STE provision to be through a STL oriented science (or its sub-components) and technology education, or through a STL oriented science and technology provision (techno-science), at least for the compulsory years of schooling, where specialisation is not contemplated.

2.   **recognising the goal of STE** should be taken to be scientific and technological literacy for all (STL) (ICASE, 2001). This ensures any STE policy is:

    (a)   in line with those for education as a whole;

    (b)   in line with promoting greater student interest and intended to lead to greater public awareness and understanding of the role played by science and technology in the lives of students now and in the future;

    (c)   for lifelong learning, reflecting the future needs of the country and encompassing moral, ethical, societal, and culturally dependent values;

    (d)   emphasising the need for understanding and having an awareness of the importance of sustainable development with respect to issues in the local society and the importance of the role of STE in developing responsible citizenry;

    (e)   promoting equity relevant to STL, ensuring the educational aims empower women for life in their society and allow full opportunities for students from all backgrounds;

    (f)   able, in recognition of globalisation, to realise that policies need to be implemented which are in harmony with those developed in other countries;

    (g)   encouraging the interaction between science and technology educators. An important approach to this is for Governments to support the Project 2000+ network guided by UNESCO and a group of international NGOs;

    (h)   encouraging interactions at the science and technology teacher level with the help of national, professional associations and the coordination of international NGOs such as ICASE.

3.   **making science and technology, individually or interdisciplinarily, core subjects** at basic school level for all. For this it is important to ensure they:

(a) meet the needs of all students as future citizens;

(b) enable students to make appropriate career choices;

(c) provide appropriate learning opportunities in terms of a range of educationally driven STE knowledge/skills for possible future studies in science and technology.

4. **setting school 'standards'** for scientific and technological literacy requirements in terms of (i) conceptual development, (ii) scientific and technological processes, (iii) personal development, (iv) cooperative and communication skills, as well as (v) socio-scientific values, all carefully screened to be appropriate for the students' aptitude, prior learning/age and social environment. These 'standards' need to be flexible to respond to changes in science and technology, changes in the local environment and to society and career needs; extend 'standards' to cover justifiable ethical and moral values related to science and technology related issues and an appreciation of the role STE can play in developing human rights values, a culture of peace and poverty alleviation, equity gender issues and responsible citizenry.

5. **attention should be given to the expected teaching targets and approaches**, especially with respect to relevant experiences by students, thus ensuring that STE is seen to be an integral part of the total education provision and hence playing its part in the holistic development of individuals.

6. **viewing specialization**, or optional additional course, in any STE course as the desire to **extend 'time on task'** in meeting the goals of education through science. Ensure these courses are still intended to provide suitable intellectual, attitudinal, skills and values oriented learning, leading to an enhanced level of STL.

7. **monitoring specific attitudinal targets** within STE, in terms of the positive role science and technology can play in the economic and social advancement of society; and academically, in terms of educational competence, geared to science and technology problem solving and socio-scientific decision making capabilities. It is expected such provision does not discriminate on the grounds of race, religion, ethnicity or gender, ensuring sustainable development, responsible citizenry and equity practices in STE at all levels and with adequate steps taken to promote practices for the empowerment of women and the inclusion of marginalised groups.

8. **encourage research efforts** in the field of STE, both of a quantitative and qualitative nature. The research should

(a) cover all areas of learning and achievement;.

(b) include curriculum development and assessment practices;

(c) address diagnostic reflection of teaching and classroom action research;

(d) include the effectiveness, and the effective use of resources;

(e) cover the initial and in-service training of teachers;

(f) not only be undertaken nationally, but outcomes from research internationally should be noted;

(g) be disseminated to all interested in STE, especially teachers, through appropriate and effective mechanisms (e.g. not through written notice-board announcements);

(h)   be considered an important area for policy makers to ensure outcomes are put into practice where considered advantageous.

9.   **ensuring that assessment practices** pay attention to:

(a)   validity and are thus geared to the attainment of multi-dimensional STL;

(b)   the diagnostic evaluation of factors influencing student learning, to ensure students, both girls and boys, are not underachieving;

(c)   setting standards that ensure the assessment of students pays more attention to what students know rather than determining what they do not know;

(d)   ensuring future assessment procedures are based on the attainment of criteria or targets, ensuring assessment of students, within the STE classroom, encompass competence in communication skills, personal attributes, socially related decision–making skills, and values besides cognitive achievement; ensuring that assessment instruments are valid for the purpose for which they were intended;

(e)   promoting reliability in assessment by requiring multiple measurements of the educational attributes and expect many of these to be classroom based and carried out by the teacher during normal teaching practices;

(f)   enhancing the use of formative assessment procedures by the teacher, especially observational techniques and oral questioning, both for diagnostic purposes related to the teaching and for determining the progress of student; requiring that assessment and evaluation policies relate to an understanding and the value of science and technology learning, with respect to globalisation, sustainable development and taking appropriate social responsibility.

10.   **making adequate provision for ongoing professional support** for science and technology teachers. This should cover:

(a)   rethinking the role of science and technology teaching within a framework of STL for all;

(b)   the ability to cope with a future society- related curriculum; and above all,

(c)   the ability to ensure STE knowledge/skills are in response to relevant student interests and society needs;

(d)   proposing a policy of professional development strategies, which stress that the teaching materials and teaching approaches must be equally applicable to both boys and girls in terms of the knowledge, skills and values to be imparted through STE teaching and for the cultural and social environment.

11.   ensuring professional development is not only confined to science and technology teachers. Steps should be taken to provide **initial training and professional support to the 'trainers' of such teachers**, so they are able to provide STL oriented pre- and in-service professional help.

12.   **supporting the formation and functioning of non-Governmental science and technology professional, subject teacher associations**, covering primary and secondary teacher, teacher educators and others involved with science and technology education. The major purpose for this is the professional development of, and support available to, teachers at a practical level. This professional peer support should be

equipped to help to ensure that teachers are able to share ideas and practices at the local level, and through international links, at the regional and international levels.

B. Recommendations to Curriculum Developers

Curriculum Developers should be trained to make STE more relevant to the perceived needs and interests of students, reflecting a balance view of the importance and functioning of industry and giving an awareness of careers; and meeting the needs of society and the culture by:

1.   ensuring that science and technology curricula contain a clear statement of aims, making it explicit why it is considered valuable for all to study this area, and what they should gain from the experience. These aims should relate, first and foremost to all stated **goals of education** and indicate the role of STE in meeting the education needs of students, which can be easily understood by teachers, students and parents;

2   determining how the curriculum can

   (a)   reflect, and be seen to reflect, the statement of aims;

   (b)   be compiled to reflect the emphasis that an *education through science and technology* should place on the various aims in attaining the stipulated goals of education;

   (c)   recognise that the goal of education *through science and technology* requires teaching that promotes intellectual qualities, personal development, societal attributes and communication skills of students as a basis, a direction and a stimulation for positive science and technology attitudes;

   (d)   besides conveying ideas of education through *science*, the curriculum should convey the *science* and technology ideas by which the educational goals can be expected to be attained and incorporate important ideas *about-science and technology*, that is, ideas about the ways in which reliable knowledge of the natural and man-made world has been, and is being, obtained;

   (e)   ensuring that science and technology curricula integrate elements designed to enhance 'literacy', and those designed as the early stages of a 'specialist' training in science. The major goal of STE, irrespective of type of course, or calibre of students, should be STL;

3.   recognize that STE should be a core provision for all students and hence can be expected to plays its part in the achievement of all the goals of education; the general goals of education, viewed from a science and technology education perspective, are those to attain multi-dimensional STL.

4.   ensuring curricula match **'standards'** for scientific and technological literacy in terms of (i) conceptual development, (ii) scientific process, (iii) personal development, (iv) cooperative and communication skills, as well as (v) socio-scientific values, all carefully screened to be appropriate for the students' aptitude, prior learning/age and social environment. The matching of 'standards' need to be flexible to respond to changes in science and technology, changes in the local environment and to society and career needs;

5.   ensuring that STE courses promote a better understanding of science and technology in society, through

   (a)   developing student abilities to solve problems utilizing science and technology principles and assist students to be comfortable with making

societal decisions incorporating science, technology and mathematics alongside economics, environmental, political and social considerations;

(b)   recognising the role of STE is promoting education geared to raising public awareness, public understanding of aspects relevant to society and in raising the popularity of science and technology subjects;

(c)   including appropriate strategies enabling students to examine issues geared to sustainable development, developing positive attitudes and to recognise the roles to be undertaken by a STL responsible person;

(d)   making science and technology courses more popular among students, both girls and boys. This should be through increased relevancy to everyday life geared to the local, national or even global perspective as well as the world of work and leisure;

(e)   recognising distance learning and information technology procedures should be seen as playing a unique role in STE. Greater learning opportunities through distance learning should to be developed for teachers to utilise;

(f)   recognising that science and technology knowledge is increasing at a faster and faster rate and hence selection of content, for school science and technology curricula, should not be based solely on fundamental science and technology ideas for fear that science and technology, relevant to society issues and concerns, does not get taught. [Basing curricula on context rather than content allows students greater opportunity to take control over their learning];

(g)   recognising that relevant science and technology curricula should incorporate interdisciplinary STL ideas and should be expected to prepare students to address concerns and issues about health; food; energy; land, water and minerals resources; the environment; industry; and information technology;

(h)   recognising the importance of sustainable development in a global economy and in providing science and technology contexts and activities to promote skills and attitudes needed by students to become responsible citizens;

(i)   ensuring that science and technology curricula are carefully constructed so as to promote equity for all in acquiring STL and be seen to be presented in a manner relevant to both boys and girls;

(j)   being prepared, in a world of increasing knowledge and the growth and availability of multiple sources of knowledge, to move away from viewing the textbook as the only STE teaching resource. Greater use of the society (museums, centres, libraries, the internet and even its people) as a resource should be promoted.

6.   **viewing specialization**, or optional additional course, in any STE course as the desire to **extend 'time on task'** in meeting the goals of *education through science and technology*, leading to an enhance level of STL; ensuring these courses are still intended to provide suitable intellectual, attitudinal, skills and values oriented learning, befitting *education through science and technology* at a higher multi-dimensional STL level.

7.   promoting

   (a)   a positive image of science and technology within the curriculum (units such as pollution are not contemplated);

   (b)   a positive role that science and technology plays in the economic and social advancement of society;

   (c)   scientific problem solving;

   (d)   socio-scientific decision making capabilities, which do not discriminate on the grounds of race, religion, ethnicity or gender,

   (e)   ensuring sustainable development, responsible citizenry and equity practices in STE at all levels; and

   (f)   adequate steps are taken to promote values related to the empowerment of women and the inclusion of marginalised groups.

8.   undertaking research into the development and evaluation of the suitability of the curriculum in meeting the goals of STE and enabling students to reach a multi-dimensional level of STL.

9.   **ensuring that feedback and assessment practices** recommended pay attention to:

   (a)   validity and are thus geared to the attainment of STL;

   (b)   the diagnostic evaluation of factors influencing student learning, to ensure students, both girls and boys, are not underachieving;

   (c)   promoting activities that ensure assessment of students pays more attention to what students know rather than determining what they do not know;

   (d)   ensuring activities undertaken by students, within the STE classroom, encompass competence in communication skills, personal attributes, socially related decision–making skills, and values as well as cognitive achievement;

   (e)   enhancing the use of formative assessment procedures by the teacher, especially observational techniques and oral questioning, both for diagnostic purposes related to the teaching and in determining the progress of student; requiring that assessment and evaluation policies relate to an understanding and the value of science and technology learning with respect to globalisation, sustainable development and taking appropriate social responsibility.

10.   **making adequate provision for ongoing professional support** for science and technology teachers. This should cover:

   (a)   rethinking the role of science and technology teaching within a framework of STL for all;

   (b)   the ability to cope with a future society- related curriculum; and above all,

   (c)   the ability to ensure STE knowledge/skills are in response to relevant society needs, proposing a policy of professional development strategies, which stress that the teaching materials and teaching approaches must be equally applicable to both boys and girls in terms of the knowledge, skills and values to be imparted through STE teaching and for the cultural and social environment.

11.   ensuring professional development is not only confined to science and technology teachers. Take steps to provide **initial training and professional support to the**

'trainers' of such teachers, so they are able to provide the pre- and in-service professional help.

12. **supporting the formation and functioning of non-Governmental science and technology professional, subject teacher associations**, covering primary and secondary teacher, teacher educators and others involved with science and technology education so as to aid the professional development of, and support available to, teachers at a practical level. This professional peer support should be equipped to help to ensure that teacher are able to share ideas and practices at the local level, and through international links, at the regional and international levels.

C. Recommendations to Teachers of Science and Technology Subjects

Teachers of science and technology subjects should make STE more relevant to the perceived needs and interests of students, reflecting a balance view of the importance and functioning of industry and giving an awareness of careers; and meeting the needs of society and the culture by:

1. be aware, and appreciate the implications of, the goals of science and technology education being derived from the general goals of education and are hence wider than the acquisition of knowledge, or what constitutes science and/or technology content;

2. ensuring that STE is made relevant to the interests of all students. It is expected that much attention is paid to:

    (a) issues and concerns brought to the lesson by the students based on their lives and their concerns and, where appropriate for science and technology learning, the teaching takes into account the prior learning of students;

    (b) the STE goals for students as being to achieve a high multi-dimensional level of STL.

    (c) recognising that the expectations for STL teaching is the promotion of conceptual learning, acquiring process skills, personal and societal skills and values, as a basis, a direction and a stimulation for positive science and technology attitudes, encouraging students to aspire to a more diverse and great level of STL throughout life.

3. endorsing the view that STE should be a core provision in the school curricula, made available to all students based on the same general goals (derived from the goals of education);

4. promote **school 'standards'** for scientific and technological literacy requirements

    (a) in terms of (i) conceptual development, (ii) scientific process, (iii) personal development, (iv) cooperative and communication skills, as well as (v) socio-scientific social values, all carefully screened to be appropriate for the students' aptitude, prior learning/age and social environment,

    (b) geared to 'standards' flexible to respond to changes in science and technology, changes in the local environment and to society and career needs;

    (c) extending 'standards' to cover justifiable ethical and moral values based on science and technology related issues, and

    (d) appreciating the role STE can play in responsible citizenry or values for human rights, a culture of peace and poverty alleviation.

5. ensuring the teaching includes

    (a) recognising that STE needs to be undertaken in schools in a manner designed to make the subjects popular and providing a background that will lead to public awareness of the importance of science and technology;

    (b) utilising approaches that actively involve students, both girls and boys in participatory learning and place greater emphasis on learning for transference, rather than memorizing. The emphasis needs to be on what students acquire

rather than what is presented; values education as an important component of STE for all; the promotion of ethical positions and social responsibility need to be a part of science and technology teaching alongside economic, environmental, and political considerations;

(c)   ensuring science and technology teaching relates to local issues and concerns. The relevance of the role of STE in guiding justifiable decisions and practices to solving problems needs to be overt in the eyes of students;

(d)   being aware of the growing creation of new technologies in society and orient teaching towards a future having currently unknown developments and situations; use teaching approaches which ensure students: are at the centre of the classroom, helping to define content and activities; are active inquirers involved in resolution of real life problems;

(e)   ensuring that STE, being culturally bound, related to the society in which it is being taught. Co-operative skills, innovative development, creative skills and critical thinking are important for the development of students and the recognition of the place of science in society. STE practices need to promote these attributes;

(f)   being encouraged to develop their own meaning for experiences they have and experiments they do, define learning by what they can do and how they can use information and skills in new contexts;

(g)   ensuring students show an understanding and appreciation of sustainable development in the context of their environment, their cultural and social background and the decisions expected of a responsible person;

(h)   ensuring students are willing to show strong values of equity, empowerment of women and fairness to all as a result of the teaching strategies and feedback used by ST teachers. This needs to be developed in the face of local superstitions and believes, which are judged contrary to human rights;

(i)   being aware that STL involves experiences as well as interactions within society;

(j)   needs of employers, especially from industry, that employees possess skills of problem solving and decision-making skills, together with personal attributes such as initiative, ingenuity and perseverance, and ensure students acquire such attributed through education, of which STE is an important part;

(k)   teaching students to justify ethical positions utilising sound science and technology knowledge, related to the local, national and global arena;

(l)   use of strategies to motivate students to recognise the role of STE in promoting human rights and in acquiring a holistic concept of, and the need for, a culture of peace;

(m)   relating to and utilise, research findings about children's learning and constructivism; to teaching approaches, which provide a stimulating learning environment; and to valid feedback or assessment/diagnostic practices;

(n)   maintaining strong links with social science teachers and interrelate with their practices to promote human rights, a culture of peace and poverty alleviation. Links with UNESCO and international NGOs need to be promoted to share ideas related to moral and ethics values;

6. **viewing specialization**, or optional additional course, in any STE course as the desire to **extend 'time on task'** in meeting the goals of *education through science and technology;* ensure these courses are still intended to provide suitable intellectual, attitudinal, skills and values oriented learning, leading to an enhanced level of STL. The general goals and hence the enhancing of STL needs to be understood as being the same, whether the course is viewed as 'specialisation' or a terminal class'.

7. **monitoring specific attitudinal targets** within STE, in terms of the positive role science and technology can play in the economic and social advancement of society; and academically, in terms of educational competence, geared to science and technology problem solving and social decision making capabilities (of which science and technology play a part), which do not discriminate on the grounds of race, religion, ethnicity or gender, ensuring sustainable development, responsible citizenry and equity practices in STE at all levels and that adequate steps are taken to promote practices for the empowerment of women and the inclusion of marginalised groups.

8. recognise the importance of diagnostic feedback research and other action research practices in supporting the promotion of effective STE; being aware of research in STE both nationally and internationally;.

9. **ensuring that assessment practices** pay attention to:

   (a)   being an integral part of teaching and learning and be more susceptible to developments shown to be effective by research;

   (b)   using feedback as a crucial component of teaching, and specifying, for achievement, criteria or targets as well as use multiple measures of attainment;

   (c)   validity and are thus geared to the attainment of STL;

   (d)   the diagnostic evaluation of factors influencing student learning, to ensure students, both girls and boys, are not underachieving;

   (e)   setting assessment standards that ensure assessment of students pays more attention to what students know rather than determining what they do not know;

   (f)   ensuring future assessment procedures are based on the attainment of criteria or targets, ensuring assessment of students, within the STE classroom, encompass competence in communication skills, personal attributes, socially related decision–making skills, and values as well as cognitive achievement, ensuring that assessment instruments are valid for the purpose for which they were intended;

   (g)   promoting reliability in assessment by requiring multiple measurements of the educational attributes and expect many of these to be classroom based and carried out by the teacher during normal teaching practices;

   (h)   enhancing the use of formative assessment procedures by the teacher, especially observational techniques and oral questioning, both for diagnostic purposes related to the teaching and in determining the progress of student; requiring that assessment and evaluation policies relate to an understanding and the value of science and technology learning with respect to globalisation, sustainable development and taking appropriate social responsibility.

10. **be willing to participate in ongoing professional support** for science and technology teachers related to :

(a) rethinking the role of science and technology teaching within a framework of STL for all;

(b) the ability to cope with a future socio- scientific related curriculum; and above all,

(c) the ability to ensure STE knowledge/skills are in response to relevant society needs,

(d) stressing that the teaching materials and teaching approaches must be equally applicable to both boys and girls in terms of the knowledge, skills and values to be imparted through STE teaching and for the cultural and social environment.

11. support the suggestion that professional development is not only confined to science and technology teachers. Steps should be taken to provide **initial training and professional support to the 'trainers' of such teachers**, so they are able to provide the pre- and in-service professional help.

12. **supporting the formation and functioning of non-Governmental science and technology professional, subject teacher associations**, covering primary and secondary teacher, teacher educators and others involved with science and technology education so as to aid the professional development of, and support available to, teachers at a practical level. This professional peer support should be equipped to help to ensure that teacher are able to share ideas and practices at the local level, and through international links, at the regional and international levels.

D. Recommendations to Teacher Educators (for Pre-service and In-service Provisions)

Teacher Educators should be trained to guide teachers of science and technology subjects to make STE more relevant to the perceived needs and interests of students, reflecting a balance view of the importance and functioning of industry and giving an awareness of careers; and meeting the needs of society and the culture by:

1.   ensuring teachers:

   (a)   appreciate the overall purpose of teaching and the place of STE within this;

   (b)   are able to address the integration of the full range of educational goals within the context of teaching science and technology; and

   (c)   have knowledge related to the effectiveness of teaching related to the overall goals of education;

2.   guiding teachers to recognise that the goal of STE is multi-dimensional STL

3.   ensuring teachers accept that STE should be a core subject provision in schools and that students need to be prepared for, and to appreciate the need for, lifelong learning in a changing world.

4.   expect standards to be set for the STE provision and that these include relevance to the needs of society, as well as appropriate for the needs of the students.

5.   recognising the difficulty teachers face and ensuring teachers are 'trained' to:

   (a)   interrelate ethics and social responsibility with scientific knowledge and skills;

   (b)   taking note of the outcomes of research undertaken and measures suggested to put positive outcomes into practice, especially those geared to public awareness and understanding;

   (c)   change their role from imparting knowledge to enabling learners to develop skills, possess positive attitudes and stress evaluation for diagnostic purposes in their teaching;

   (d)   use a wide variety of teaching methods and approaches;

   (e)   realise that their students will handle new technologies and hence the students must be educated to cope with the future unknown;

   (f)   move away from using the textbook as their only resource and make greater use of the society, the local environment and, as appropriate, the internet as a resource ;

   (d)   are trained to utilise constructivist ideas and able to build on students' experiences in their teaching;

   (e)   make students:
   -    the centre of the classroom attention, helping to define content and activities;
   -    active inquirers involved in resolution of real life problems;
   -     willing to develop their own meaning for experiences they have and for

experiments they perform;

(f)   define learning by what students can do and how they can use information and skills in new contexts;

(g)   are aware that their role is not one of imparting knowledge, but one of promoting skills and attitudes related to local, national and relevant global issues;

(h)   are flexible and have the ability to adapt material for the local situation. [It needs to be recognized that it takes skill to turn informational material into a teaching and learning resource];

(i)   see investigatory work as very important to solve problems. Professional development needs to ensure teachers recognize the role of experimental work in enhancing personal development and that following experimental recipes with little learning (especially using unfamiliar chemicals and specialist apparatus) is an expensive and unnecessary luxury];

(j)   are more aware of STE research and its relevance. [Make provision for teachers to be involved in action research at both local and through international co-operation, at global levels with a view to raising the awareness by students of the need for a responsible citizenry];

(k)   recognise that relevant STE relates to the world of the student (at the local, regional or universal levels). The guidance needs to enable teachers to interrelate the ST concepts with the societal, technological developments, which are relevant to the students' world;

(l)   are able to make changes in curricula so they better suit their students (the curriculum should suit the students, rather than the students following an inappropriate curriculum). Guidance is needed to help teachers address appropriate curriculum change based on a sound philosophy and the use of a range of resources including radio, TV, libraries, videotape, CD-roms, internet and science centres/museums;

(m)   are able to put forward STE activities that enable students to gain and develop values associated with sustainable development and responsible citizenry;

(n)   address the full range of educational goals, especially the need for educating students for tolerance, the promotion of a culture of peace, human rights and poverty alleviation;

(o)   are able to teach in an equitable manner appropriate for both boys and girls, adapting to the aptitudes, interests, abilities, cultural diversity and prior learning of all students;

6.   stressing that the offering of optional or extended courses (so-called specialist courses) still need to conform to STL and having the same general goals related to education.

7.   stress the need for teachers to monitor students attitudes towards STE and that a positive attitude is essential for learning; ensure teachers recognise that relevance of teaching is a crucial factor for maintaining a positive attitude.

8.   recognise that they are needed to be at the forefront of research in STE, to guide the respectability of the research from an educational point of view, and to be aware of research developments worldwide.

9.   ensure teachers are able to base assessment strategies on:

(a)   the attainment of criteria or targets. [Criteria referenced assessment needs to relate to all aspects of education that are to be achieved through STE i.e. intellectual development, personal attributes and social values];

(b)   validity and not unduly weighted towards lower order cognitive skills, nor ignoring that the STE provision is education through science and technology;

(c)   undertaking multiple measurements of the educational attributes to be gained by students to increase reliability. [Such multiple measures need to involve the teacher playing an active role in the continuing assessment of students and in the diagnostic determination of the success of the teaching];

(d)   being able to assess students' performance focussing on students' ability to understand and interpret scientific information, to discuss controversial issues, as well as on their knowledge and understanding of ST ideas relevant to the social setting;

10.   recognise that professional development provisions for teachers are important and that this is an on-going need in which teacher educators are expected to play an important role.

11.   accept that the teacher educators also need professional development and that practicing teachers can assist in one component of this.

12.   recognise the need to play a strong role in supporting professional STE teacher associations and appreciate that they can play an important role in supporting teachers by:

(a)   providing teaching ideas, guidance and support;

(b)   provide opportunity to be able to interact with other teachers and share ideas:

(c)   informing teachers of links through international NGO organisations. Teachers need to be made aware of the role of UNESCO and international NGOs in supporting the teaching of ST;

(d)   helping them to form links with social workers and others involved in problems of social inequity, non-empowerment of women and the marginalisation of minority groups.

E. Recommendations to External Examination Authorities/Bodies and their personnel

Examiners of science and technology subjects should recognise their role in making STE more relevant to the perceived needs and interests of students, reflecting a balance view of the importance and functioning of industry and giving an awareness of careers; and meeting the needs of society and the culture by:

1. recognising that the goals of science and technology education relate to the goal of education as a whole and that examiners, along with curriculum developers, are required to be able to interpret this so as to ensure valid learning by students.

2. appreciate that the teaching within STE is to achieve a multi-dimensional level of STL.

3. recognising that the STE provision is intended for all students, encompassing widely different interests and aspirations and hence any assessment measure of success needs multiply components to cope with the diversity.

4. aware of, and able to interpret for given situations, the standards to be set for the STE provision.

5. recognise that the teaching of *education through science and technology* involves values education, personal development, conceptual development within science and technology and also skills in undertaking various processes in science and technology. All this is in addition to science and technology conceptual development, problem solving and socio-scientific decision making.

6. note that the overall goals of science and technology education do not change, even when one group of students differs from another. And extension of the science and technology education provision for one group over another is intended to provide the opportunity for greater promotion of multi-dimensional STL.

7. appreciate that student attitude is important in STE teaching and that any impact of examinations affects the attitude of students, the teaching, probably the textbook and certainly the emphases placed on the teaching of various components of STE.

8. ensure adequate research is undertaken on all external assessment/examination practices to

    (a) determine their validity and reliability,

    (b) comparability with aspects such as expectations against standards, achievement patterns in previous years, achievements in other subject areas, etc.

9. reflecting seriously on

    (a) the validity of assessment practices used for any formal external examination system, and to ascertain their negative influence on ongoing teacher practices within the classroom towards the promotion of STL;

    (b) ensuring that valid assessment strategies cover intellectual (especially higher order skills), personal, communicative and social value skills with an appropriate conceptual situation. It is not sufficient to assess content

knowledge. Attention needs to be given to the assessment of skills in scientific method, personal development and social skills, especially those related to problem solving and decision making;

(c)   recognising that student attitudes and personal skills such as perseverance, creativity, initiative, ingenuity and regard for safety procedures are expected to form part of the assessment strategy for STE;

(d   recognising that techniques need to be introduced to assess student abilities to undertake decision-making and use appropriate communication skills in a societal context;

(e)   noting that equity issues need to form part of the assessment strategy for students on STE courses and for the evaluation of STE practices. Note also that assessment procedures used to test for an understanding and appreciation of equity issues are expected to be relevant to the students' environment, culture and aptitude.

10.   appreciate the need for examination personnel to be involved in assisting the professional development of teachers.

11.   appreciate the need for examination personnel to be involved in the professional development of the 'trainers' of teachers and to interact with such personnel on research developments affecting assessment practices and directions.

12.   recognise the important role that can be played by professional STE teacher associations and to seek advice from, and to give guidance to, such bodies.

F.   Recommendations to UNESCO and International NGOs

UNESCO and International NGOs should make STE more relevant to the perceived needs and interests of students, reflecting a balance view of the importance and functioning of industry and giving an awareness of careers; and meeting the needs of society and the culture by:

1.   supporting Governments, teacher educators, curriculum developers and professional teacher associations in recognizing the goals and trends in science and technology education and the research developments taking place;

2.   supporting Governments, teacher educators, curriculum developers and professional teacher associations in efforts to ensure the STE provision is in line with Project 2000+ and STL for all;

3.   supporting Governments, teacher educators, curriculum developers and professional teacher associations in efforts to make STE a core subject in the school curriculum and a basis for lifelong learning, towards greater awareness of science and technology within a changing society.

4.   support Governments, teacher educators, curriculum developers and professional teacher associations in setting up suitable standards for the STE provision within the country, or region.

5.   setting up a mechanism for the collection and dissemination of information and of examples of effective STE practice at community level for the benefit of teachers, teacher educators, curriculum developers and examination personnel.

6.   support Governments, teacher educators, curriculum developers and professional teacher associations in recognising the value of STL targets at a multi-dimensional level and to gear all STE provisions, at whatever level, to this goal.

7.   assist Governments, teacher educators, curriculum developers and professional teacher associations in monitoring the STE provision within school and especially the attitudes of students towards the relevance of science and technology; encourage and assist research in STE within the country, or region.

8.   encourage, support and play a strong role in the dissemination of research efforts in STE within a country at Governmental and non-Governmental levels.

9.   support Governments, teacher educators, curriculum developers and professional teacher associations in setting up valid and reliable assessment procedures for STE.

10   encouraging the provision of greater professional development for STE teachers.

11   encouraging the provision of greater professional development for science and technology teacher educators, both from institutions and from professional associations.

12   encourage and support Governments to recognise the value of, and need for, professional STE teacher associations, which can play an important role in:

(a)   raising standard and morale among STE teachers;

(b)   aiding the exchange of resources and expertise, the interaction of teachers and the exchange of ideas;

(c)   facilitating the sharing of resources, research findings, curriculum strategies and exchange of ideas for the classroom. [International NGOs should be supported to form links with national and sub-national groups];

(d)   conducting research and surveys on developments in STE and the manner in which STE is playing its role within education in promoting public awareness and popularity of science, ensuring human rights a culture of peace and poverty alleviation, promoting responsible citizens and sustainable development and ensuring equity, the empowerment of women and the inclusion of minority and marginalised groups.

G. Recommendations to National Science and Technology, Professional, Teacher Associations)

Science and Technology Education Teacher Associations should make STE more relevant to the perceived needs and interests of students, reflecting a balance view of the importance and functioning of industry and giving an awareness of careers; and meeting the needs of society and the culture by:

1. guiding teachers to recognise that the goals of STE should be derived from, and relate to, the goals of education; assist Governments, curriculum developers, teacher educators, examination personnel and teachers in the interpretation of this.

2. appreciate that the target for STE is multi-dimensional STL for all; be able to appreciate the philosophy driving this and put forward approaches for its operationalisation in the classroom.

3. guide Governments that the STE should be a core provision for all students, at all levels of schooling and to guide teachers that the place of Biology, Chemistry and Physics as separate entities, unrelated in their approach, is a thing of the past; guide teachers to recognise that, either a science (or science and technology) course provision is provided, or where separate sub-components are offered that these have strong inter-relationships..

4. expect standards to be set for the STE provision and that these include relevance to the needs of society, as well as appropriate for the needs of the students.

5. continue to provide support for STE teachers to assist them in their teaching in terms of materials, moral support and guidance; also ensuring the teaching includes

    (a) values education as an important component of STE for all. Ethics and social responsibility need to be a part of science and technology teaching alongside economic, environmental, and political considerations in socio-scientific decision-making;

    (b) meeting the needs of employers, especially from industry, i.e. employees possess skills of problem solving and decision-making skills, together with personal attributes such as initiative, ingenuity and perseverance, and ensure students acquire such attributed through education, of which STE is an important part;

    (c) use of strategies to motivate students to recognise the role of STE in promoting human rights and in acquiring a holistic concept of, and the need for, a culture of peace;

    (d) teaching students to justify ethical positions utilising sound science and technology knowledge, related to the local, national and global arena;

    (e) ensuring STM teaching relates to local issues and concerns in addressing sustainable development and the social responsibilities of citizens. The relevance of the role of STE in guiding justifiable decisions and practices to solving problems needs to be overt in the eyes of students,

    (f) maintaining strong links with social science teachers and interrelate with their practices to promote human rights, a culture of peace and poverty alleviation.

Links with UNESCO and international NGOs need to be promoted to share ideas related to research into assessment strategies for moral and ethics values;

(g) recognising that STE needs to be undertaken in schools in a manner designed to make the subjects popular and providing a background that will lead to public awareness of the importance of science and technology;

(h) utilising approaches that actively involve students, both girls and boys in participatory learning and place greater emphasis on learning for transference, rather than memorizing. The emphasis needs to be on what students acquire rather than what is presented;

(i) relating to and utilise, research findings about children's learning and constructivism; to teaching approaches, which provide a stimulating learning environment; and to valid feedback or assessment/diagnostic practices;

(j) ensuring that STE, being culturally bound, related to the society in which it is being taught. Co-operative skills, innovative development, creative skills and critical thinking are important for the development of students and the recognition of the place of science in society. STE practices need to promote these attributes;

(k) being aware of the growing creation of new technologies in society and orient teaching towards a future having currently unknown developments and situations; use teaching approaches which ensure students: are at the centre of the classroom, helping to define content and activities; are active inquirers involved in resolution of real life problems;

(l) being encouraged to develop their own meaning for experiences they have and experiments they do, define learning by what they can do and how they can use information and skills in new contexts;

(m ensuring students show an understanding and appreciation of sustainable development in the context of their environment, their cultural and social background and the decisions expected of a responsible person;

(n) ensuring students are willing to show strong values of equity, empowerment of women and fairness to all as a result of the teaching strategies and feedback used by ST teachers. This needs to be developed in the face of local superstitions and believes, which are judged contrary to human rights;

(o) being aware that STL involves experiences as well as interactions within society;

6. stressing to teachers that the offering of optional or extended courses (so-called specialist courses) still need to conform to STL and having the same general goals related to education.

7. stress the need for teachers to monitor students attitudes towards STE and that a positive attitude is essential for learning; recognise that relevance of teaching in the eyes of students is a crucial factor for maintaining a positive attitude.

8. encourage, and where appropriate, coordinate research into STE, especially at the classroom level, take steps to make teachers aware of research developments within the country and internationally, and play an effective role in the dissemination of research findings to classroom teachers.

9.	guide teachers to base assessment on
	(a)	the attainment of criteria or targets. [Criteria referenced assessment needs to relate to all aspects of education that are to be achieved through STE i.e. intellectual development, personal attributes and social values];
	(b)	measures that ensure the assessment of students is valid and not unduly weighted towards lower order cognitive skills, nor ignoring that the STE provision is education through science and technology;
	(c)	undertaking multiple measurements of the educational attributes to be gained by students to increase reliability. [Such multiple measures need to involve the teacher playing an active role in the continuing assessment of students and in the diagnostic determination of the success of the teaching];
	(d)	students' performance, focusing on students' ability to understand and interpret scientific information, to discuss controversial issues, as well as on their knowledge and understanding of ST ideas relevant to the social setting;
10.	recognise that professional development provisions for teachers are important and that this is an on-going need in which professional STE associations can, and should, play a large role in:
	(a)	helping teachers appreciate the purpose of science and technology teaching
	(b)	guide teachers in suitable ways to interpret the curriculum and operationalise the goals of teaching science and technology
	(c)	assisting teachers in resource provisions and their utilisations
	(d)	overcoming constraints in teaching
	(e)	assisting teachers provide constructivist teaching, avoiding misconceptions
	(f)	assist teachers to use sound techniques and new practices
	(g)	making teachers aware of research developments, assist them in conducting research efforts of their own, encourage interaction of teachers related to research development and put forward ways in which research findings can be operationalised in the classroom
	(h)	help teachers with feedback and assessment procedures, both formative and summative and in interpreting the requires of external examiners
	(i)	acting as a buffer between teachers and policy makers, curriculum developers, external examiners, the scientific community and industry and making known teachers views, concerns and suggestions.
11.	accept that the trainers of teachers also need professional development and that teacher associations can assist in this.

12.	appreciate that professional STE teacher associations can play an important role in supporting teachers by:
	(a)	provide opportunity to be able to interact with other teachers and share ideas:

	(b)	informing teachers of links through international NGO organisations. Teachers need to be made aware of the role of UNESCO and international NGOs in supporting the teaching of ST;

	(c)	helping them to form links with social workers and others involved in problems of social inequity, non-empowerment of women and the marginalisation of minority groups.

H.   Recommendations to Industrialists

Industrialists should help to make STE more relevant to the perceived needs and interests of students, reflecting a balance view of the importance and functioning of industry and giving an awareness of careers; and meeting the needs of society and the culture by:

1.   recognise that the aims of STE relate, first and foremost to the **goals of education** and hence there is a big difference between science and technology education (the science and technology in schools) and specialist instruction to become a scientist/ technologist (largely seen as a tertiary education component).

2.   recognising the curriculum

    (a)   is expected to reflect the statement of aims;

    (b)   is compiled to reflect the emphasis that an *education through science and technology* can place on playing its part in attaining the stipulated goals of education;

    (c)   is based on the goals of education *through science and technology* and teaching of science and technology is promoting intellectual qualities, personal development, societal attributes and communication skills of students as a basis, a direction and a stimulation for positive science and technology attitudes;

    (d)   besides conveying ideas of education through *science and technology*, it is expected to convey the *science* and technology knowledge by which the educational goals can be expected to be attained and also incorporate important ideas *about-science and technology*, that is, ideas about the ways in which reliable knowledge of the natural and man-made world has been, and is being, obtained;

    (e)   tries to ensure that science and technology curricula integrate elements designed to enhance 'literacy', and those designed as the early stages of a 'specialist' training in science. The major goal of STE, irrespective of type of course, or calibre of students, is expected to be STL;

3.   recognize that STE needs to be a core provision for all students and hence can be expected to plays its part in the achievement of all the goals of education; the general goals of education become the general goals of STE.

4.   ensuring curricula match **'standards'** for scientific and technological literacy in terms of (i) conceptual development, (ii) scientific process, (iii) personal development, (iv) cooperative and communication skills, as well as (v) socio-scientific social values, all carefully screened to be appropriate for the students' aptitude, prior learning/age and social environment. The matching of 'standards' need to be flexible to respond to changes in science and technology, changes in the local environment and to society and career needs;

5.   supporting STE courses that promote a better understanding of science and technology in society through

    (a)   developing student abilities to solve problems utilizing science and technology principles and assist students to be comfortable with making societal decisions

incorporating science, technology and mathematics alongside economics, environmental, political and social considerations;

(b)   recognising the role of STE as promoting education geared to raising public awareness, public understanding of aspects relevant to society and in raising the popularity of science and technology subjects;

(c)   including appropriate strategies enabling students to examine issues geared to sustainable development, develop positive attitudes and to recognise the roles to be undertaken by a STL responsible person;

(d)   making science and technology courses more popular among students, both girls and boys. This should be through increased relevancy to everyday life geared to the local, national or even global perspective as well as the world of work and leisure;

(e)   recognising that science and technology knowledge is increasing at a faster and faster rate and hence selection of content for school science and technology curricula should not be based solely on fundamental science and technology ideas for fear that science and technology, which is relevant to society issues and concerns, does not get taught. Basing curricula on content rather than contexts allows students little opportunity to take strong control over their learning;

(f)   recognising that relevant science and technology curricula should incorporate interdisciplinary STL ideas and should be expected to prepare students to address concerns and issues about health, food, energy, land, water and minerals resources, the environment, industry and information technology;

(g)   recognising the importance of sustainable development in a global economy and provide science and technology contexts and activities to promote the skills and attitudes needed by students to become responsible citizens;

6.   **viewing specialization**, or an optional additional component, in any STE course as the desire to **extend 'time on task'** in meeting the goals of education through science and technology, leading to an enhance level of STL; ensure these courses are still intended to provide suitable intellectual, attitudinal, skills and values oriented learning befitting education through science and technology at a more intensive level.

7.   promote a positive image of science and technology (units such as pollution should not be contemplated) and the positive role science and technology can play in the economic and social advancement of society; and academically, in terms of educational competence, geared to science and technology problem solving and socio-scientific decision making capabilities, which do not discriminate on the grounds of race, religion, ethnicity or gender, ensuring sustainable development, responsible citizenry and equity practices in STE at all levels and that adequate steps are taken to promote practices for the empowerment of women and the inclusion of marginalised groups.

8.   appreciate the need for research and evaluation in the field of STE, especially with respect to teaching resources and the manner in which they are used in the classroom, the effectiveness of visits to industry and industry involvement in the classroom.

9.   **recognise the need for feedback and assessment practices** to pay attention to:

(a)   validity and reliability;

(b)   the diagnostic evaluation of factors influencing student learning, to ensure students, both girls and boys, are not underachieving;

(c)   promoting activities that ensure assessment of students pays more attention to what students know rather than determining what they do not know;

(d)   ensuring activities undertaken by students, within the STE classroom, encompass competence in communication skills, personal attributes, socially related decision–making skills, and values as well as cognitive achievement;

10.   **support the need for adequate provision for ongoing professional support** for science and technology teachers.

11.   **support the need for adequate provision for ongoing professional support** for **the 'trainers' of such teachers**, so they are able to provide the pre- and in-service professional help.

12.   **supporting the formation and functioning of non-Governmental science and technology professional, subject teacher associations**, covering primary and secondary teacher, teacher educators and others involved with science and technology education so as to aid the professional development of, and support available to, teachers at a practical level.

I.   Recommendations to Scientists/Researchers (Science Academies)

Scientists should help make STE more relevant to the perceived needs and interests of students, reflecting a balance view of the importance and functioning of industry and giving an awareness of careers; and meeting the needs of society and the culture by:

1.   being prepared to recognise that the aims of STE relate, first and foremost to the **goals of education** and hence there is a big difference between science and technology education (the science and technology in schools) and instruction to become a scientist/technologist (usually reserved for the tertiary level)

2.   recognising the curriculum

(a)   reflects the statement of aims,

(b)   is compiled to reflect the emphasis that an education through science and technology can place on playing its part in attaining the stipulated goals of education;

(c)   is based on the goal of education *through science and technology* and where teaching is promoting intellectual qualities, personal development, societal attributes and communication skills of students as a basis, a direction and a stimulation for positive science and technology attitudes;

(d)   besides conveying ideas of education through *science and technology*, it should convey the *science and technology knowledge* by which the educational goals can be expected to be attained and incorporate important ideas *about-science and technology*, that is, ideas about the ways in which

reliable knowledge of the natural and man-made world has been, and is being, obtained;

    (e)   tries to ensure that science and technology curricula integrate elements designed to enhance 'literacy', and those designed as the early stages of a 'specialist' training in science. The major goal of STE, irrespective of type of course, or calibre of students, should be multi-dimensional STL and linked to this, higher order cognitive skills;

3.   recognize that STE needs to be a core provision for all students, irrespective of aptitude and hence can be expected to plays its part in the achievement of all the goals of education; the general goals of education become the general goals of STE.

4.   ensuring curricula match **'standards'** for scientific and technological literacy in terms of (i) conceptual development, (ii) scientific process, (iii) personal development, (iv) cooperative and communication skills, as well as (v) socio-scientific social values, all carefully screened to be appropriate for the students' aptitude, prior learning/age and social environment. The matching of 'standards' need to be flexible to respond to changes in science and technology, changes in the local environment and to society and career needs, but rigorous in ensuring skills of learning to learn and higher order reasoning ability;

5.   supporting STE courses that promote a better understanding of science and technology in society through:

    (a)   developing student abilities to solve problems utilizing science and technology principles and assist students to be comfortable with making socio-scientific decisions, incorporating science, technology and mathematics alongside economics, environmental, political and social considerations;

    (b)   recognising the crucial need of STE to promote education geared to raising public awareness, public understanding of aspects relevant to society and in raising the popularity of science and technology subjects;

    (c)   including appropriate strategies enabling students to examine issues geared to sustainable development, develop positive attitudes and to recognise the role to be undertaken by a STL responsible person in society;

    (d)   making science and technology courses more popular among students, both for girls and boys. This should expected to be through increased relevancy to everyday life geared to the local, national or even global perspective, as well as the world of work and leisure; the approach to science and technology education should not be expected to be from abstract scientific or technological ideas, but from a societal perspective utilising constructivist principles;

    (e)   recognising that science and technology knowledge is increasing at a faster and faster rate and hence selection of content for school science and technology curricula is crucial; this selection should not be based, solely on fundamental science and technology ideas for fear that science and technology, which is relevant to society issues and concerns, does not get taught. Basing curricula on contexts rather than content allows students greater opportunities to take strong control over their learning (emphasising students learning, rather than teachers teaching);

(f)   recognising that relevant science and technology curricula should incorporate interdisciplinary STL ideas and should be expected to prepare students to address concerns and issues about health; food; energy; land, water and minerals resources; the environment; industry; and information technology;

(g)   recognising the importance of sustainable development in a global economy and provide science and technology contexts and activities to promote the skills and attitudes needed by students to become responsible citizens;

6.   **viewing specialization**, or optional additional components, in any STE course as the desire to **extend 'time on task'** in meeting the goals of education through science, leading to an enhance level of STL; ensure these courses are still intended to provide suitable intellectual, attitudinal, skills and values oriented learning befitting education through science and technology at a more intensive level and are NOT abandoning the goals of education in favour of knowledge cramming;

7.   promote a positive image of science and technology (units such as pollution should not be contemplated) and the positive role science and technology can play in the economic and social advancement of society; gearing the teaching towards science and technology problem solving and socio-scientific decision making capabilities, which do not discriminate on the grounds of race, religion, ethnicity or gender, ensuring sustainable development, responsible citizenry and equity practices in STE at all levels and that adequate steps are taken to promote practices for the empowerment of women and the inclusion of marginalised groups.

8.   recognise that much research in the area of STE falls within social science research techniques, as it is dealing with persons (students and teachers), where variables cannot be controlled. Encourage STE research and recognise the need for stress to be placed on validity and reliability factors for meaningful outcomes and to appreciate the inability to undertake multiple measures in a controlled environment.

9.   **recognise the need for feedback and for assessment practices** in STE to pay attention to:

(a)   validity, and within this, reliability;

(b)   the diagnostic evaluation of factors influencing student learning, to ensure students, both girls and boys, are not underachieving;

(c)   promoting activities that ensure assessment of students pays more attention to what students know rather than determining what they do not know;

(d)   ensuring activities undertaken by students, within the STE classroom, encompass competence in communication skills, personal attributes, socially related decision–making skills, and values as well as cognitive achievement;

10.   **support the need for adequate provision for ongoing professional support** for science and technology teachers; be willing to assist in the knowledge updating components of professional support.

11   **support the need for adequate provision for ongoing professional support** for **the 'trainers' of such teachers**, so they are able to provide the pre- and in-service professional help.

12   **supporting the formation and functioning of non-Governmental science and technology professional, subject teacher associations**, covering primary and secondary teacher, teacher educators and others involved with science and technology

education so as to aid the professional development of, and support available to, teachers at a practical level.

J. Recommendations to Science Centres (Museums)

Science Centres should help make STE more relevant to the perceived needs and interests of students, reflecting a balance view of the importance and functioning of industry and giving an awareness of careers; and meeting the needs of society and the culture by:

1. being prepared to recognise that the aims of STE relate, first and foremost to the **goals of education** and hence there is a big difference between science and technology education (the science and technology in schools) and instruction to become a scientist/technologist (usually reserved for the tertiary level)

3. recognising that in promoting science and technology to students, the school curriculum

    (a)   reflects the statement of aims;

    (b)   is compiled to reflect the emphasis that an education through science and technology can place on playing its part in attaining the stipulated goals of education;

    (c)   is based on the goal of education *through science and technology* and where teaching is promoting intellectual qualities, personal development, societal attributes and communication skills of students as a basis, a direction and a stimulation for positive science and technology attitudes;

    (d)   besides conveying ideas of education through *science and technology*, it should convey the *science and technology knowledge* by which the educational goals can be expected to be attained and incorporate important ideas *about-science and technology*, that is, ideas about the ways in which reliable knowledge of the natural and man-made world has been, and is being, obtained;

    (e)   tries to ensure that science and technology curricula integrate elements designed to enhance 'literacy', and those designed as the early stages of a 'specialist' training in science. The major goal of STE, irrespective of type of course, or calibre of students, should be multi-dimensional STL and linked to this, higher order cognitive skills;

3. recognize that STE should be a core provision for all students, irrespective of aptitude and hence can be expected to plays its part in the achievement of all the goals of education; the general goals of education become the general goals of STE. With this in mind, science centres can play a useful role in complementing the school provision.

4. recognise that school curricula need to match **'standards'** for scientific and technological literacy in terms of (i) conceptual development, (ii) scientific process, (iii) personal development, (iv) cooperative and communication skills, as well as (v) socio-scientific social values, all carefully screened to be appropriate for the students' aptitude, prior learning/age and social environment. The matching of 'standards' need to be flexible to respond to changes in science and technology, changes in the local environment and to society and career needs, but rigorous in ensuring skills of learning to learn and higher order reasoning ability;

5. supporting STE courses, through science centre exhibits and other activities, which are designed to promote a better understanding of science and technology in society through:

    (a) developing student abilities to solve problems utilizing science and technology principles and assist students to be comfortable with making socio-scientific decisions, incorporating science, technology and mathematics alongside economics, environmental, political and social considerations;

    (b) recognising the crucial need of STE to promote education geared to raising public awareness, public understanding of aspects relevant to society and in raising the popularity of science and technology subjects;

    (c) including appropriate strategies enabling students to examine issues geared to sustainable development, develop positive attitudes and to recognise the role to be undertaken by a STL responsible person in society;

    (d) making science and technology courses more popular among students, both for girls and boys. This should expected to be through increased relevancy to everyday life geared to the local, national or even global perspective, as well as the world of work and leisure; the approach to science and technology education should not be expected to be from abstract scientific or technological ideas, but from a societal perspective utilising constructivist principles;

    (e) recognising that science and technology knowledge is increasing at a faster and faster rate and hence selection of content for school science and technology curricula is crucial; this selection should not be based, solely on fundamental science and technology ideas for fear that science and technology, which is relevant to society issues and concerns, does not get taught. Basing curricula on contexts rather than content allows students greater opportunities to take strong control over their learning (emphasising students learning, rather than teachers teaching);

    (f) recognising that relevant science and technology curricula should incorporate interdisciplinary STL ideas and should be expected to prepare students to address concerns and issues about health; food; energy; land, water and minerals resources; the environment; industry; and information technology;

    (g) recognising the importance of sustainable development in a global economy and provide science and technology contexts and activities to promote the skills and attitudes needed by students to become responsible citizens;

6. **viewing specialization**, or optional additional components, in any STE course in schools as the desire to **extend 'time on task'** in meeting the goals of education through science and technology, leading to an enhance level of STL; recognise these courses are still intended to provide suitable intellectual, attitudinal, skills and values oriented learning befitting education through science and technology at a more intensive level and are NOT abandoning the goals of education in favour of knowledge cramming;

7. promote a positive image of science and technology (pollution should not be the major focus, but rather how science and technology help to combat pollution) and the positive role science and technology can play in the economic and social advancement of society; gearing the student involvements towards science and technology problem

solving and socio-scientific decision making capabilities, which do not discriminate on the grounds of race, religion, ethnicity or gender, ensuring sustainable development, responsible citizenry and equity practices in STE at all levels and that adequate steps are taken to promote practices for the empowerment of women and the inclusion of marginalised groups.

8.   recognise that much research in the area of STE and hence research in science centres falls within social science research techniques, as it is dealing with persons, where variables cannot be controlled. Encourage STE research and recognise the need for stress to be placed on validity and reliability factors for meaningful outcomes and to appreciate the inability to undertake multiple measures in a controlled environment.

9.   **recognise the need for feedback and for assessment practices** in STE to pay attention to:

(a)   validity, and within this, reliability;

(b)   the diagnostic evaluation of factors influencing student learning, to ensure students, both girls and boys, are not underachieving;

(c)   promoting activities that ensure assessment of students pays more attention to what students know rather than determining what they do not know;

(d)   ensuring activities undertaken by students, encompass competence in communication skills, personal attributes, socially related decision–making skills, and values as well as cognitive achievement;

10.   **support the need for adequate provision for ongoing professional support** for science and technology teachers; be willing to assist in the knowledge updating components of professional support.

11.   **support the need for adequate provision for ongoing professional support** for **the 'trainers' of such teachers**, so they are able to provide the pre- and in-service professional help.

12   **supporting the formation and functioning of non-Governmental science and technology professional, subject teacher associations**, covering primary and secondary teacher, teacher educators and others involved with science and technology education so as to aid the professional development of, and support available to, teachers at a practical level.